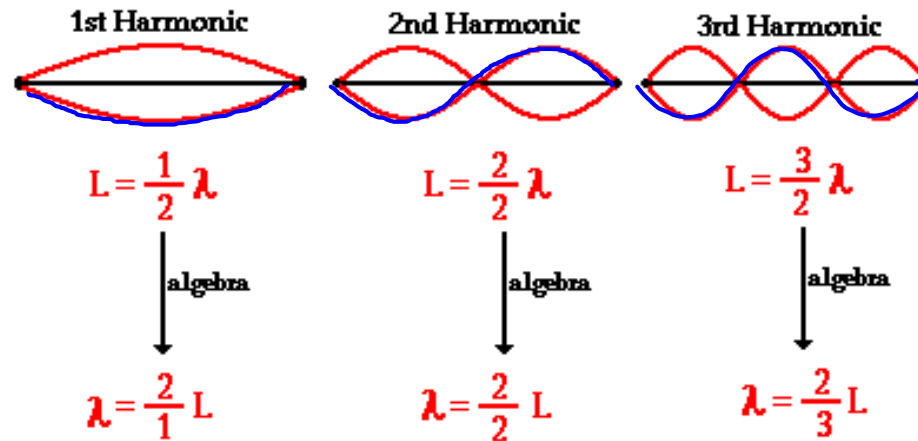


Tube Resonance

OPEN AND CLOSED TUBES

Standing Waves



$$\lambda_1 = \frac{2}{1} (1.0\text{m}) \quad \lambda_2 = \frac{2}{2} (1.0\text{m}) \quad \lambda_3 = \frac{2}{3} (1.0\text{m})$$
$$\lambda_1 = 2.0\text{m} \quad \lambda_2 = 1.0\text{m} \quad \lambda_3 = .6\bar{6}\text{m}$$

$$v_w = 160\text{m/s}$$

$$f_1 = \frac{v}{\lambda} = \frac{160\text{m/s}}{2\text{m}} = 80\text{Hz}$$

$$f_2 = \frac{v}{\lambda_2} = \frac{160\text{m/s}}{1.0\text{m}} = 160\text{Hz}$$

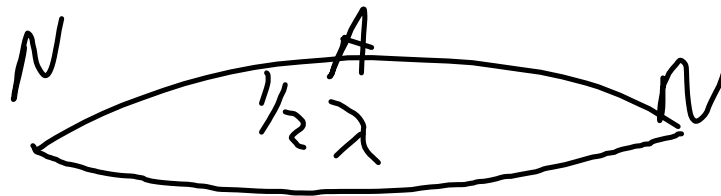
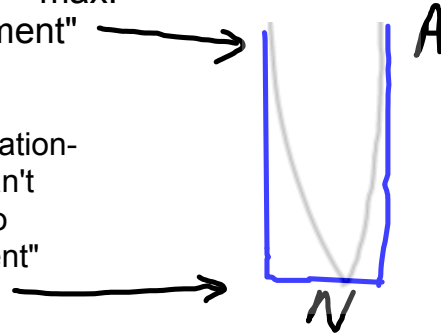
$$f_3 = \frac{v}{\lambda_3} = \frac{160\text{m/s}}{.6\bar{6}\text{m}} = 240\text{Hz}$$

Tube Resonance

<http://www.ngsir.netfirms.com/englishhtm/TwaveStatA.htm>
string

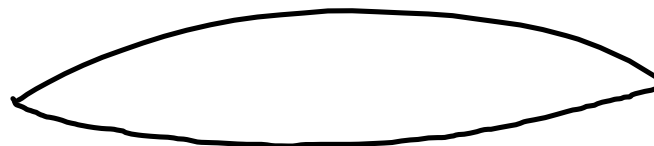
top- open termination,
particles are free to
move--- "max.
displacement"

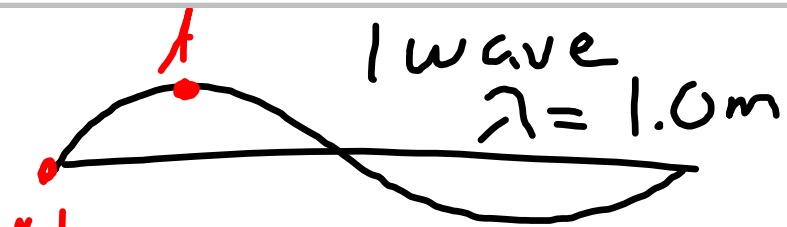
rigid termination-
particles can't
move----"no
displacement"
- node



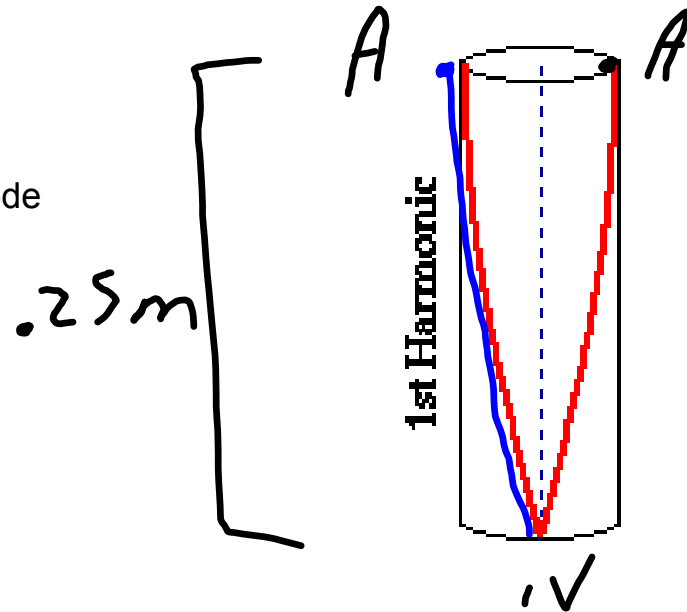
N = no particle
displacement-
node

A = maximum particle
displacement- *antinode*





.25 m from a node
 to an antinode



closed termination

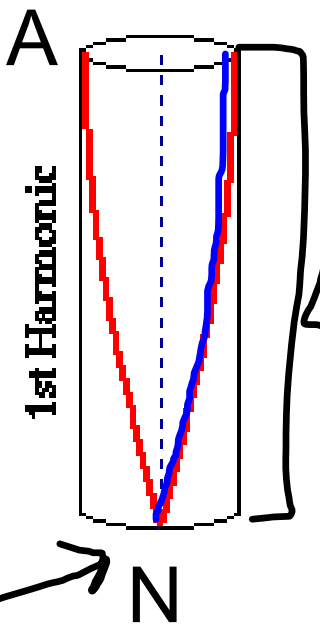
$$v = f \lambda$$

$$f = \frac{v}{\lambda} = \frac{340\text{m/s}}{1\text{m}}$$

$$f = 340\text{Hz}$$

at *antinode* particles are free to move and have max. displacement

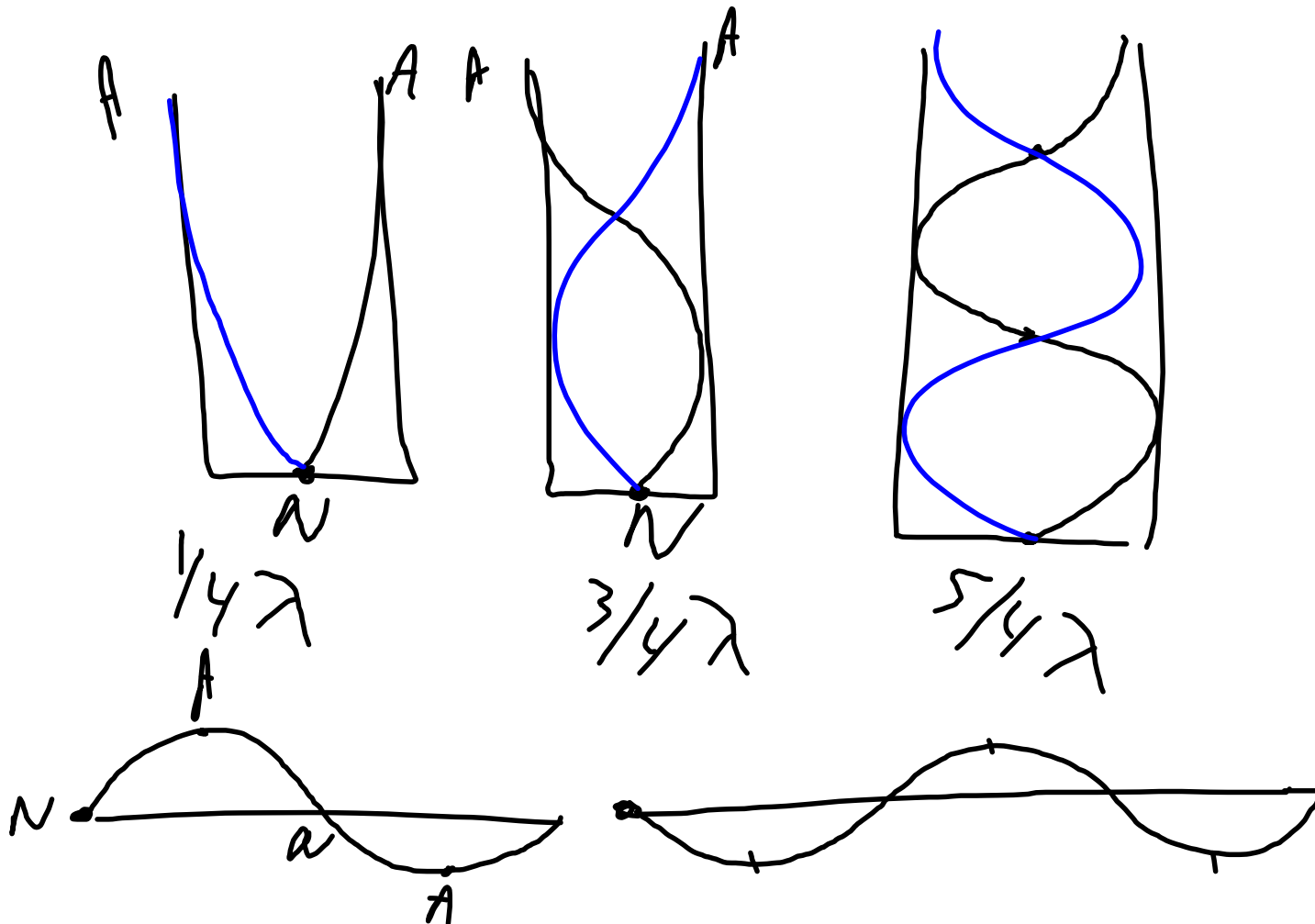
because of rigid termination there is a *node* at the closed end of the tube



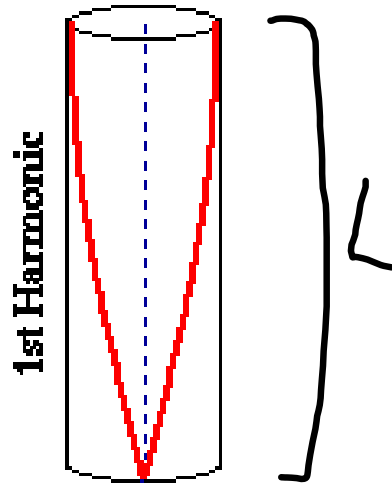
incident pulse
reflected pulse

$$\frac{1}{4} \lambda = L$$
$$\lambda = 4L$$

other possible arrangements of nodes and antinodes of waves that will resonate in the closed tube



$$L = 30 \text{ cm}$$



①

$$L = \frac{1}{4} \lambda_1$$

$$\lambda_1 = \frac{4}{1} L$$

$$\lambda_1 = \frac{4}{1} (30 \text{ m})$$

$$\lambda_1 = 1.2 \text{ m}$$

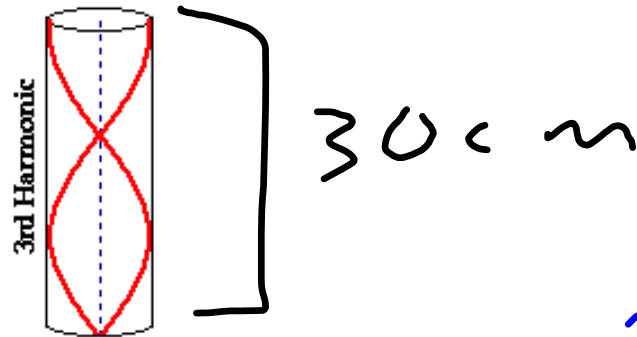
$$v_s = 340 \text{ m/s}$$

$$\lambda_1 = 1.2 \text{ m}$$

$$\therefore f_1 = \frac{v}{\lambda} = \frac{340 \text{ m/s}}{1.2 \text{ m}}$$

$$f_1 = \underline{\underline{283 \text{ Hz}}}$$

$$L = 30 \text{ cm}$$



$$L = \frac{3}{4} \lambda$$

$$\lambda = \frac{4}{3} L$$

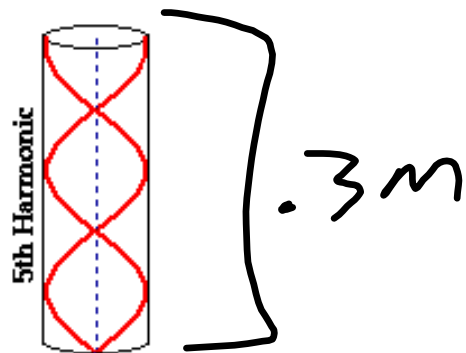
$$\lambda = \frac{4}{3} (.3 \text{ m}) = .4 \text{ m}$$

$$f = \frac{v}{\lambda}$$

$$f = \frac{340 \text{ m/s}}{.4 \text{ m}}$$

$$f = 850 \text{ Hz}$$

$$L = 30 \text{ cm}$$



$$5/4 \lambda = L$$

$$\lambda = 4/5 L$$

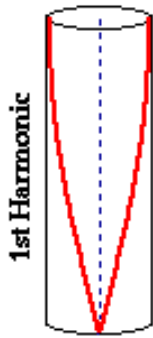
$$\therefore \lambda = 4/5 (.3 \text{ m})$$

$$\lambda = .24 \text{ m}$$

$$v = 6 \gamma$$

$$f = \frac{v}{\lambda} = \frac{340 \text{ m/s}}{.24 \text{ m}}$$

$$f = 1417 \text{ Hz}$$

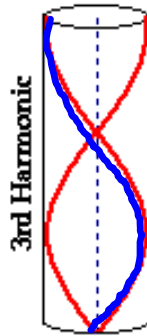


$$\frac{1}{4}\lambda$$

$$\lambda = 4L$$

$$f_1 = 283 \text{ Hz}$$

1st harmonic

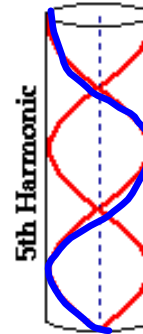


$$\frac{3}{4}\lambda$$

$$\lambda = \frac{4}{3}L$$

$$f_3 = 850 \text{ Hz}$$

3rd harmonic



$$\frac{5}{4}\lambda$$

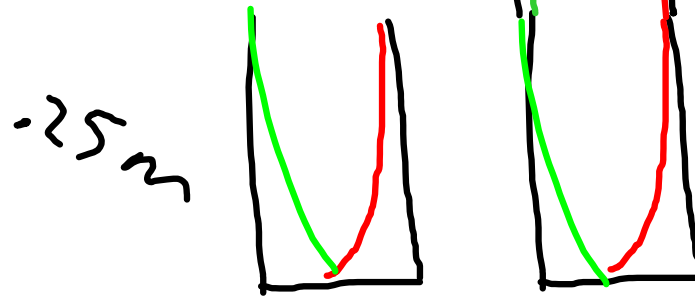
$$\lambda = \frac{4}{5}L$$

$$f_5 = 1417 \text{ Hz}$$

5th harmonic

Note that a 340 Hz sound wave will fit in a .25 m closed tube and also in a .75 m tube.

$$340 \text{ Hz}$$



$$.75 \text{ m}$$

$$\frac{3}{4} \lambda = L$$

$$\lambda = \frac{4}{3} L$$

$$\lambda = \frac{4}{3} (.75 \text{ m})$$

$$\lambda = 1.0 \text{ m}$$

$$\frac{1}{4} \lambda = L$$

$$\text{therefore, } \lambda = 4 L \quad \lambda = 4 (.25 \text{ m}) = 1.0 \text{ m}$$

$$f = \frac{340 \text{ m/s}}{1 \text{ m}} = 340 \text{ Hz}$$

Closed Tubes:

1) resonate at every
odd $\frac{1}{4} \lambda$ ($\frac{1}{4} \lambda, \frac{3}{4} \lambda, \frac{5}{4} \lambda, \frac{7}{4} \lambda, \dots$)

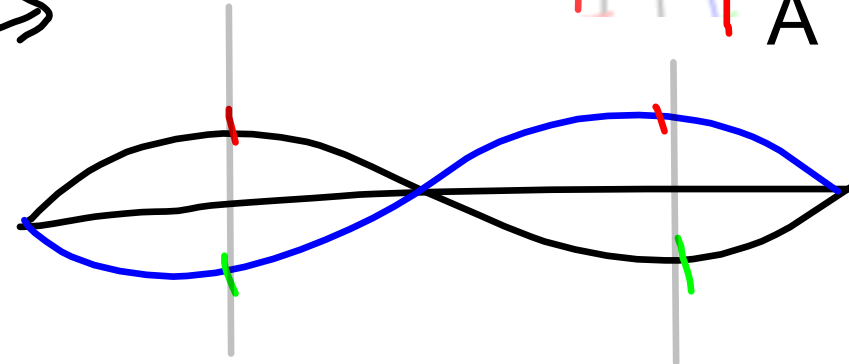
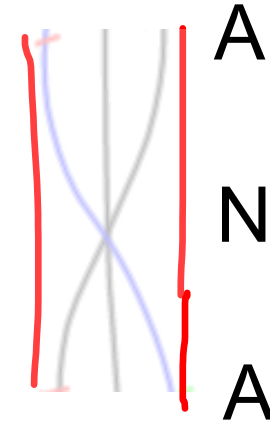
2) resonates at every
odd harmonic
 $1^{\text{st}}, 3^{\text{rd}}, 5^{\text{th}}, 7^{\text{th}}, \dots$

open

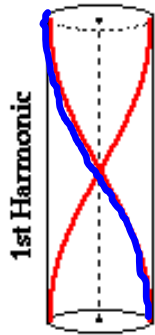
top- open termination,
particles are free to
move--- "max.
displacement"



bottom- open
termination,
particles are free to
move--- "max.
displacement"



$1/2 \lambda$ between
the antinodes



incident pulse

reflected pulse

$$\therefore \frac{1}{2} \lambda = L$$

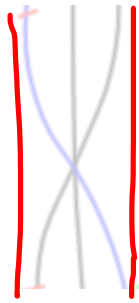
$$L = 30 \text{ cm} \quad \lambda = 2L$$

$$\lambda = 2(.30 \text{ m})$$

$$\lambda = .60 \text{ m}$$

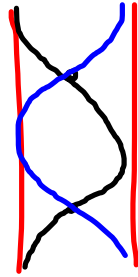
$$f = \frac{v}{\lambda} = \frac{340 \text{ m/s}}{.6 \text{ m}}$$

$$f = 567 \text{ Hz}$$



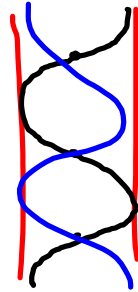
$$\frac{1}{2}\lambda = L$$

$$\lambda = 2L$$



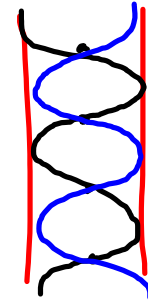
$$\frac{2}{2}\lambda = L$$

$$\lambda = L$$



$$\frac{3}{2}\lambda = L$$

$$\lambda = \frac{2}{3}L$$



$$\frac{4}{2}\lambda = L$$

$$\lambda = \frac{1}{2}L$$

$$L = 1.0 \text{ m}$$

$$\lambda_1 = \frac{2}{1}(1.0 \text{ m}) = 2 \text{ m} \quad f_1 = \frac{340 \text{ m/s}}{2 \text{ m}} = 170 \text{ Hz}$$

$$\lambda_2 = \frac{2}{2}(1.0 \text{ m}) = 1.0 \text{ m} \quad f_2 = \frac{340 \text{ m/s}}{1 \text{ m}} = 340 \text{ Hz}$$

$$\lambda_3 = \frac{2}{3}(1.0 \text{ m}) = 0.66 \text{ m} \quad f_3 = \frac{340 \text{ m/s}}{0.66 \text{ m}} = 510 \text{ Hz}$$

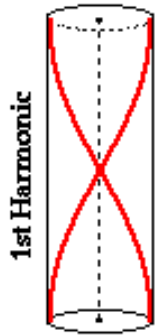
$$\lambda_4 = \frac{2}{4}(1.0 \text{ m}) = 0.5 \text{ m} \quad f_4 = \frac{340 \text{ m/s}}{0.5} = 680 \text{ Hz}$$

open tube

resonates at:

1) every $\frac{1}{2} \lambda$

2) every harmonic



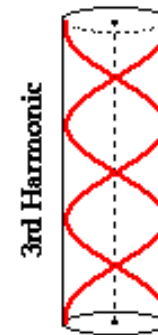
1st Harmonic

$$\frac{1}{2} \lambda = L$$
$$\lambda = \frac{2}{1} L$$



2nd Harmonic

$$\frac{2}{2} \lambda = L$$
$$\lambda = \frac{2}{2} L$$



3rd Harmonic

$$\frac{3}{2} \lambda = L$$
$$\lambda = \frac{2}{3} L$$