PIPES VERSUS STRINGS.

SOUND IN PIPES - LONGITUDINAL

AIR.

SPEED OF SOUND $v = 331\,m/s + 0.6\,T(^\circ C)$

CAME FROM. $v = \sqrt{\dfrac{B}{\rho}}$

$B = -V\left(\dfrac{\partial P}{\partial V}\right)_{\Delta Q = 0}$; $\rho = \dfrac{\text{MASS}}{\text{VOLUME}}$

$PV^{\gamma} = \text{CONSTANT}$

ADIABATIC CONNECTION

$\gamma = C_P/C_V$ < 5/3 MONATOMIC, 7/5 DIATOMIC

5/3 → 7/5 CAME FROM ROTATIONS.

$v = \sqrt{\dfrac{\gamma k_B T^{\circ}K}{M_{ATOM} \text{ OR } M_{MOLECULE}}}$

$k_B = 1.38 \times 10^{-23}\ J/^{\circ}K$.

$\lambda f = v \quad f = v/\lambda$

OPEN AT BOTH ENDS
(FLUTE - PICCOLO (SMALL FLUTE))

OPEN AT ONE END
CLOSED AT OTHER
CLARINET.
ORGAN PIPES - TYPICAL.
SAXOPHONE - CONICAL.
HOW TO DRAW PICTURES
FOR λ IN PIPES.

WAVES ON A STRING - TRANSVERSE

STRING.

$v = \sqrt{\dfrac{T}{M/L}}$

MEMBRANE

$v = \sqrt{\dfrac{T_S}{\text{MASS}/\text{AREA}}}$

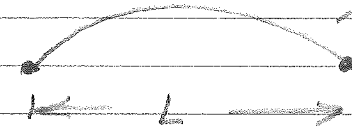
T_S = SURFACE TENSION.

NOTE - STRING TRANSFERS VIBRATIONS TO A SOUNDING BOX WHICH CAUSES AIR TO VIBRATE - SOUNDING BOX HAS ITS OWN f'S - COUPLED SYSTEM.

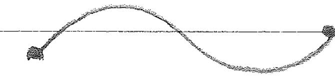
$\lambda f = v \quad f = v/\lambda$

λ:

$\lambda = 2L$.

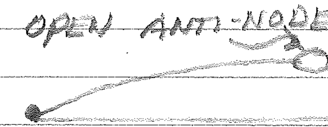


$n\lambda = 2L$



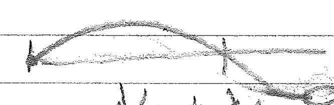
FIXED AT BOTH ENDS

OPEN ANTI-NODE



NODE

$1\lambda = 4L$



$3\lambda = 4L$

$\lambda/2 + \lambda/4$

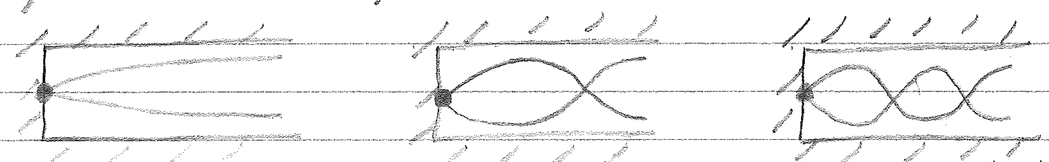
$(2n-1)\lambda = 4L$

PIPES VERSUS STRINGS

SOUND IN PIPES.
FINDING λ.

<u>FOR DISPLACEMENT</u> OF AIR MOLECULES:
OPEN ENDS ARE ANTI-NODES – LIKE FREE END OF A STRING.
CLOSED ENDS ARE NODE – ATOMS/MOLECULES CAN'T MOVE
CLOSED ENDS ARE LIKE FIXED ENDS OF A STRING.

DISPLACEMENT OPEN – CLOSED



$\leftarrow L \rightarrow$ | $\lambda/2$ | $\lambda/4$ | | λ | $\lambda/4$ |

$1\lambda = 4L$ $\quad$ $3\lambda = 4L$ $\quad$ $5\lambda = 4L$.

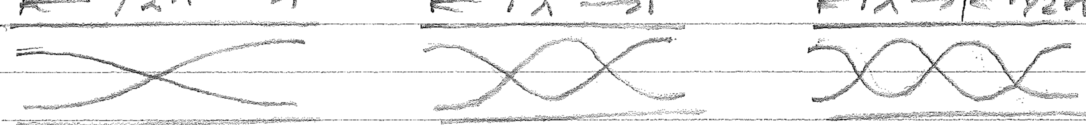
$(2n-1)\lambda = 4L. \quad n = 1, 2, 3,.$

$f = v/\lambda \quad f = v/4L, \; f = 3v/4L, \; f = \frac{5v}{4L}$

FUNDAMENTAL 1ST HARMONIC ↑ $\quad$ 3RD HARMONIC $\quad$ ↑ 5TH HARMONIC

EVEN HARMONICS MISSING

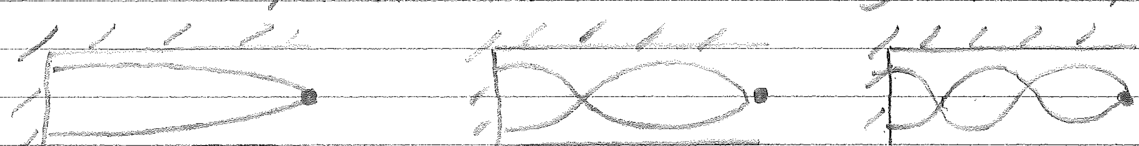
$\leftarrow \frac{1}{2}\lambda \rightarrow$ $\quad$ $\leftarrow 1\lambda \rightarrow$ $\quad$ $\leftarrow 1\lambda \rightarrow \leftarrow \lambda/2 \rightarrow$



L.

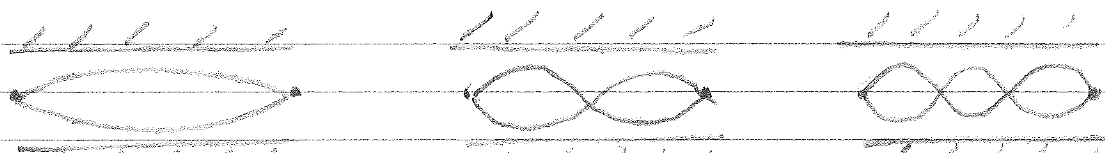
$n\lambda = 2L \quad n = 1, 2, 3.$

<u>PRESSURE</u> – AT OPEN ENDS. PUT NODE – PRESSURE GOES TO ATMOSPHERIC PRESSURE – SOUND IS A ΔP – PRESSURE VARIATIONS ABOVE – BELOW $P_{ATMOSPHERIC}$
CLOSED END PUT AN ANTI-NODE – DENSITY BUILDS UP $\Delta P \uparrow$



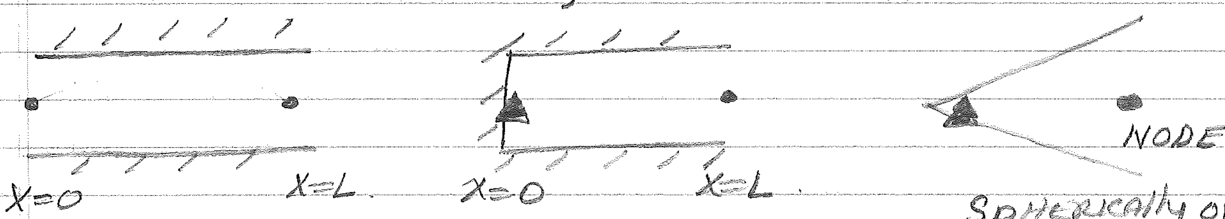
$\leftarrow \lambda/4 \rightarrow$ $\quad$ | $\lambda/4$ $\leftarrow \lambda/2 \rightarrow$ $\quad$ | $\lambda/4$ $\leftarrow \lambda \rightarrow$ |

LIKE A STRING FIXED AT BOTH ENDS.



PRESSURE IN CONICAL PIPE COMPARED TO CYLINDRICAL

OPEN END – NODE •; CLOSED END – ANTI-NODE ▲



SPHERICALLY OUTGOING WAVE

NEED $\Delta p \sim \frac{1}{r}$.

SO THAT SAME AMOUNT OF ENERGY GOES THROUGH ANY SURFACE

$\Delta p \sim \sin kx$

$\Delta p = 0 \quad x = 0$

$\Delta p = 0 \quad x = L$

$\Rightarrow kL = \pi, 2\pi$

$k = \frac{n\pi}{L} \quad n = 1, 2, \ldots$

$\lambda = \frac{2\pi}{k} = \frac{2\pi L}{n\pi}$

$n\lambda = 2L$ ✓

$\Delta p \sim \cos kx$

$\Delta p = 1 \quad x = 0$

$\Delta p = 0 \quad x = L$

$\Rightarrow kL = \frac{\pi}{2}, \frac{3\pi}{2}, \frac{5\pi}{2}, \ldots$

$k = \frac{(2n-1)\pi}{L \quad 2}$

$\lambda = \frac{2\pi}{k}$

$(2n-1)\lambda = 4L$.

* INTENSITY $I \sim (\Delta p)^2$

AREA $\sim r^2$

$r^2 \frac{1}{r^2} = 1$.

CAN'T USE

$\frac{\cos kr}{r} \to \infty$ AT $r = 0$

$\frac{\sin kr}{kr} \to 1$ AT $r = 0$

ANTI-NODE ✓

CONICAL

$\Delta p \sim \frac{\sin kr}{kr} = 0$ AT

$\Rightarrow kL = \pi, 2\pi, \ldots$

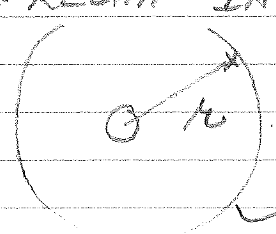
$k = \frac{n\pi}{L}$

$\Delta p \sim \frac{\sin kr}{kr}$ } SIMILAR TO open pipe

BOTH ODD & EVEN HARMONICS EXCITED.

CONICAL INSTRUMENTS – OBOE, BASSOON, ENGLISH HORN.

* RECALL INTENSITY OF SUNLIGHT FALLS AS $1/r^2$ SPHERICALLY OUTGOING WAVE



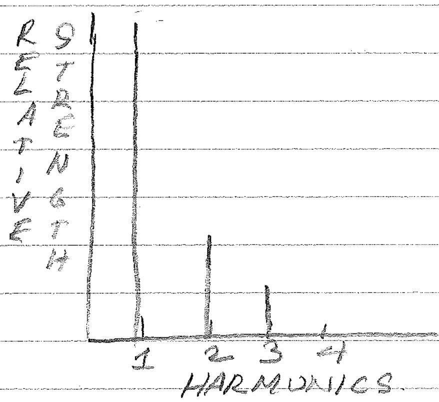
$E_{RAD} \sim \frac{1}{r} \quad I \sim E_{RAD}^2 \sim \frac{1}{r^2}$

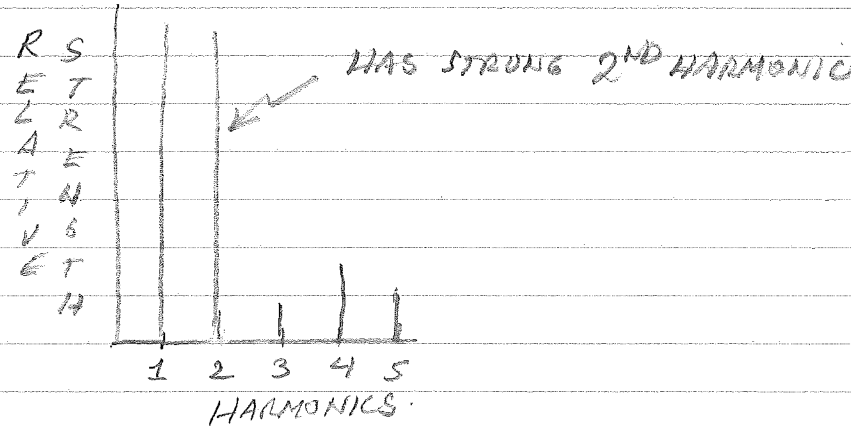
E_{RAD} ELECTRIC FIELD – RADIATION

AMOUNT OF ENERGY CROSSING SPHERE $I \times 4\pi r^2$

PIPES — WIND INSTRUMENTS

HARMONIC SPECTRUM.

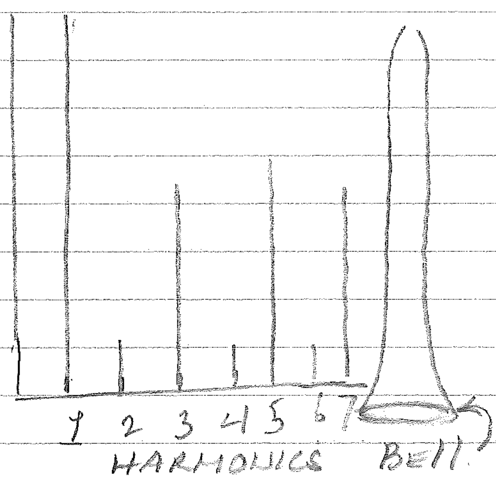


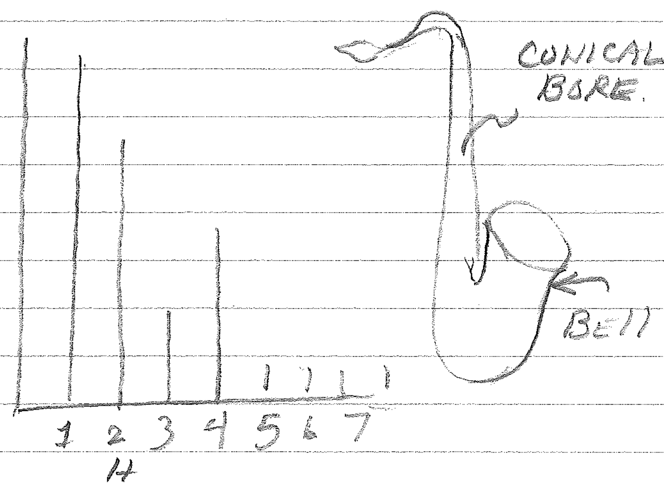


PICCOLO:

FLUTE

HAS 1/2 LENGTH OF FLUTE
PLAYS AT 2 × FUNDAMENTAL OF FLUTE





CLARINET

CYLINDRICAL BELL

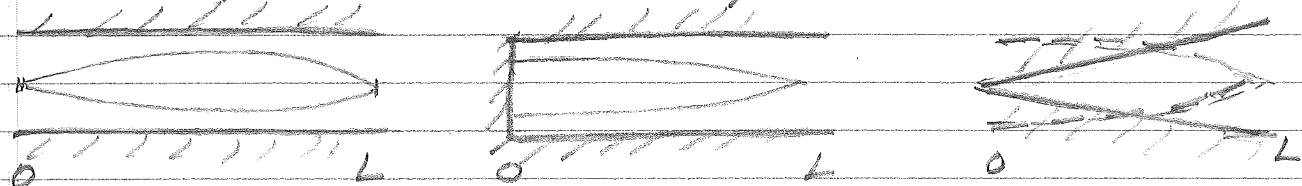
EVEN HARMONICS
WEAK.

SAXOPHONE

CONICAL BORE

ACTS MORE LIKE
OPEN-OPEN - EVEN
HARMONICS HAVE
STRONG RELATIVE STRENGTH.

BOTH OPEN | ONE SIDE OPEN | CONE

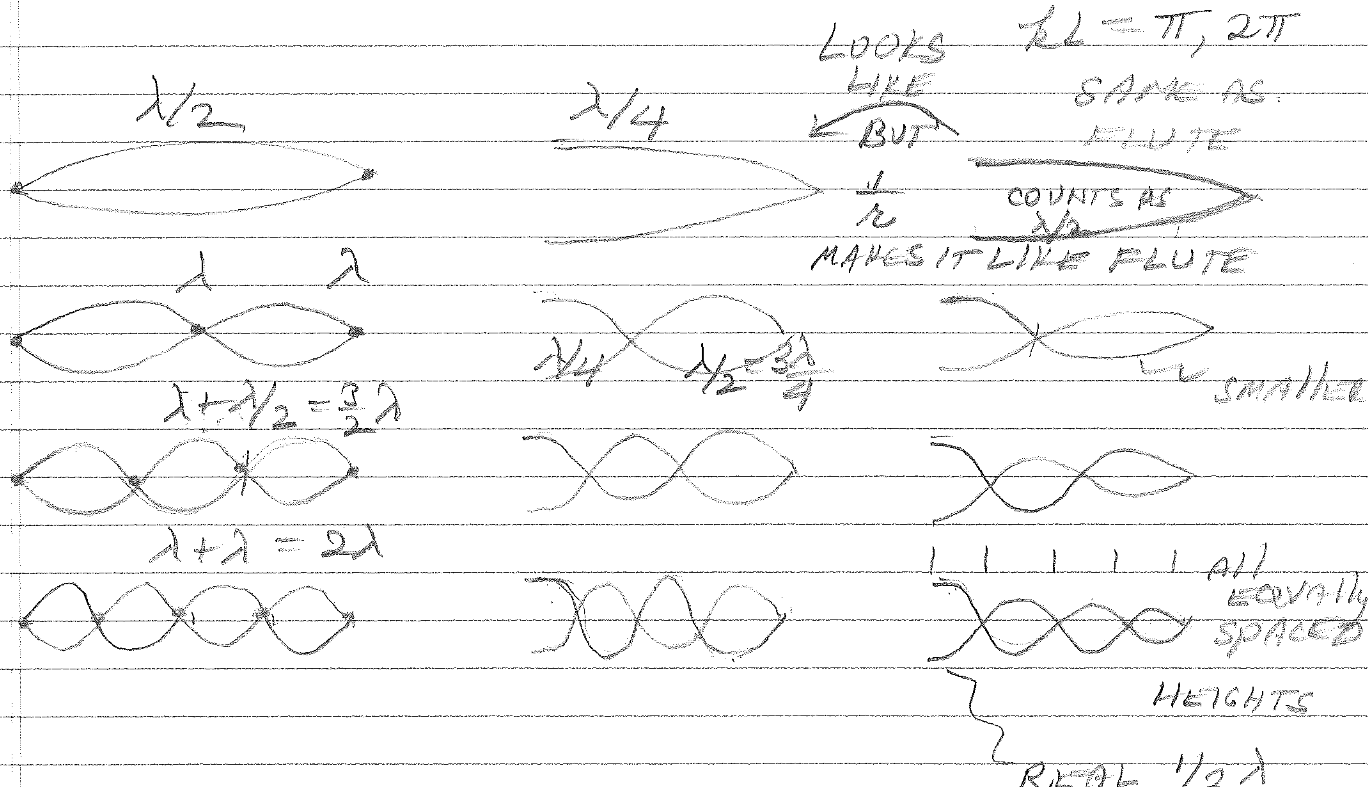


FLUTE | CLARINET | EXAGGERATE OBOE

$\sin kr$, $kL = \pi, 2\pi$

$\cos kr$, $kL = \frac{\pi}{2}, \frac{3\pi}{2}, \ldots$

$\frac{\sin kr}{r}$, $kL = \pi, 2\pi$ SAME AS FLUTE



OBOE ⟷ FLUTE

All HARMONICS

PICTURE FOR OBOE IS MISLEADING

THE FIRST NODE TO FIRST ANTI-NODE

LOOKS LIKE $\lambda/4$ BUT IS REALLY $\lambda/2$

$\frac{\sin kr}{r} \to 1$ AS $r \to 0$.

$\sin kr \to 0$ AS $r \to 0$

NEED $\frac{1}{r}$ FOR OUTGOING WAVE TO KEEP

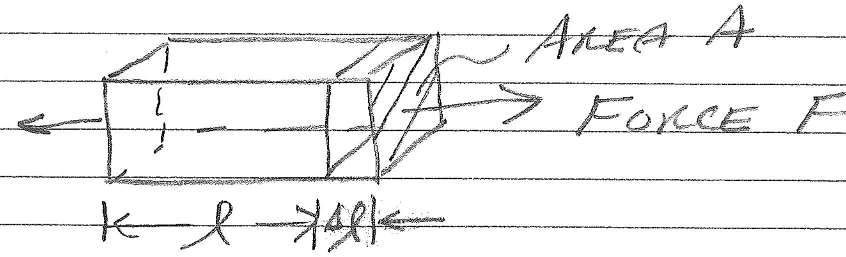
POWER $\sim (\Delta p)^2 \sim \frac{1}{r^2}$ THE SAME WHEN ⊗ BY $4\pi r^2$

I = POWER/AREA

SPEED OF SOUND IN METALS.

STRESS-STRAIN RELATIONS

YOUNGS MODULUS Y (ELASTIC MODULUS, TENSILE MODULUS)



STRESS — STRAIN

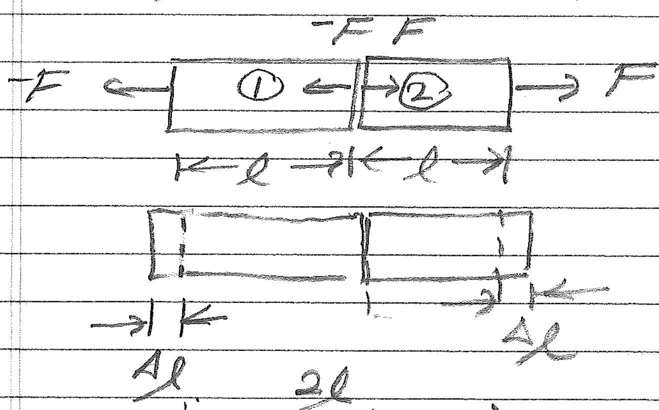
$\frac{F}{A}$ — $\Delta\ell$ - AMOUNT IT ELONGATES FROM F

$\Delta P = -B\frac{\Delta V}{V}$ — ℓ - ORIGINAL LENGTH

$$\frac{F}{A} \propto \frac{\Delta\ell}{\ell}$$

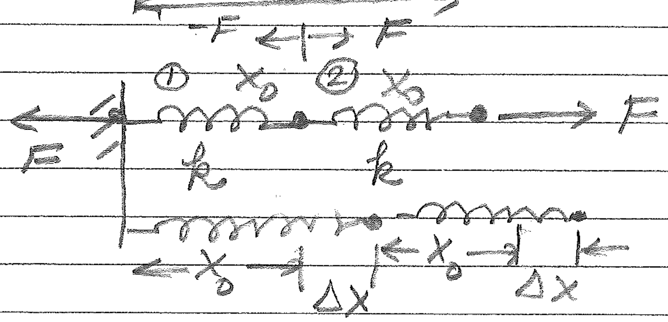
$$\frac{F}{A} = Y\frac{\Delta\ell}{\ell}$$ Y CONSTANT OF PROPORTIONALITY

① WHY ELASTICITY DEPENDS ON $\frac{\Delta\ell}{\ell}$



FOR 2ℓ GET $2\Delta\ell$.

$$\frac{2\Delta\ell}{2\ell} = \frac{\Delta\ell}{\ell}$$



$F_1 = -k\Delta x$

$F_2 = k\Delta x$

$\underline{\underline{2k\Delta x}}$

SPRING CONSTANT ~ # OF COILS.