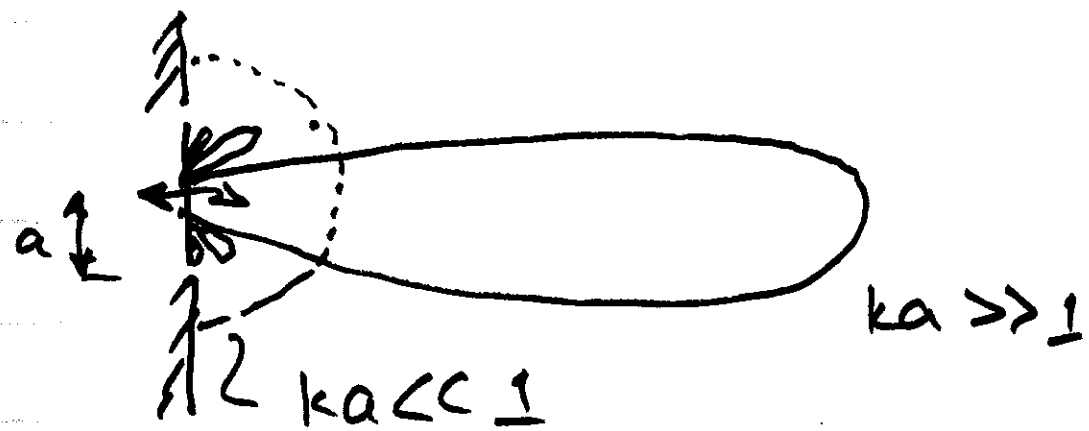
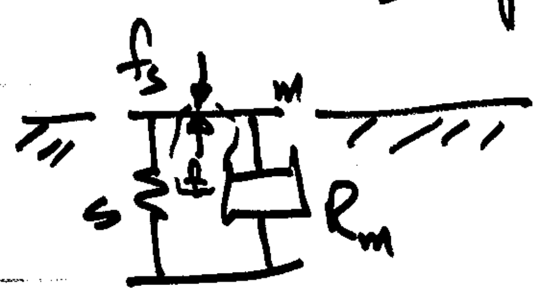
Extended Sources



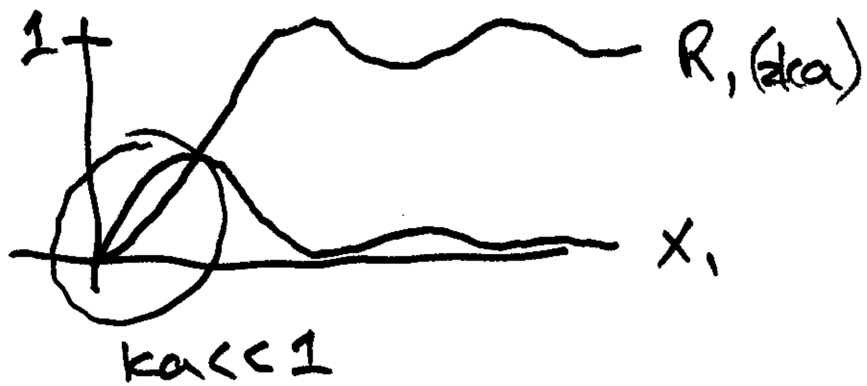
Radiation Impedance



$$Z_r = \frac{f_s}{u}$$

$$u = \frac{f}{Z_r + Z_m}$$

$$\Pi = \frac{|u|^2}{2} R_r$$



$$R_r \simeq \frac{\pi a^2}{2} \rho_0 c \, (ka)^2$$

$$X_r \simeq \pi a^2 \rho_0 c \, \frac{8}{3\pi} (ka)$$

mass-like

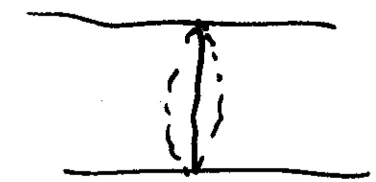
$$Z_r = R_r + j X_r$$

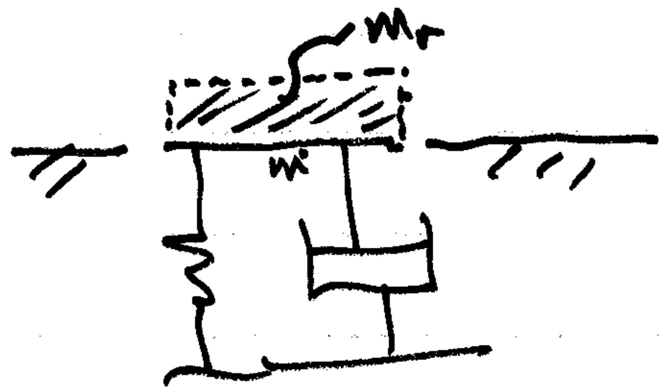
$$X_r = \omega \underbrace{m_r}_{\text{effective mass ``attached'' to piston}}$$

for $ka << 1$

$$m_r = \frac{X_r}{\omega} = \pi a^2 \rho_0 \left(\frac{8a}{3\pi}\right)$$

$$\simeq 0.85a \text{ for air}$$





$$\omega_0 = \sqrt{\frac{s}{m + m_r}}$$

added mass "usually" lowers the natural frequency of the radiator (loudspeaker)

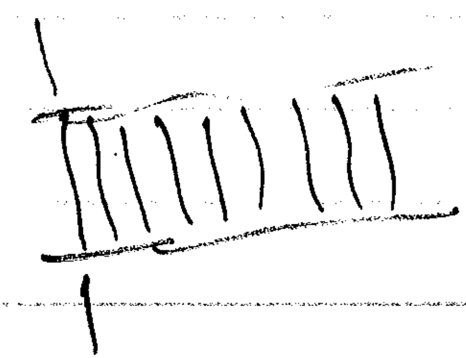
↑ $ka << 1$

high frequency $ka \gg 1$ (large piston)

$R_1(2ka) \to 1$
$X_1(2ka) \to 0$ in this case

$$Z_r \simeq R_r = \underbrace{\pi a^2}_{\text{piston area}} \rho_0 c$$

Radiated Power $ka \gg 1$



$$\Pi = \frac{1}{2} \rho_0 c \pi a^2 |\hat{u}|^2$$

$$= \underbrace{\underbrace{\frac{1}{2}|\hat{u}|^2}_{u^2_{rms}} \rho_0 c}_{\sim \text{ Intensity of freely prop plane wave}} \overbrace{S}^{\pi a^2} \text{ piston area}$$

Recall $\frac{p^2_{rms}}{\rho_0 c} = I$ for a freely propagating plane wave

since $\underline{\frac{p}{u} = \rho_0 c}$ $\quad (p^2_{rms}) = (\rho_0 c)^2 (u^2_{rms})$

$$(\rho_0 c)\, u^2_{rms} = I$$

Calculate the sound power radiated by a source based only on a knowledge of its velocity when the radiation impedance is known.

Summary

Section 7.1, 7.2, 7.4, 7.5, 7.10

Compact Sources $kD \ll 1$

simple
- monopole - volume
- dipole - point force
- quadrupole - oscillatory moment

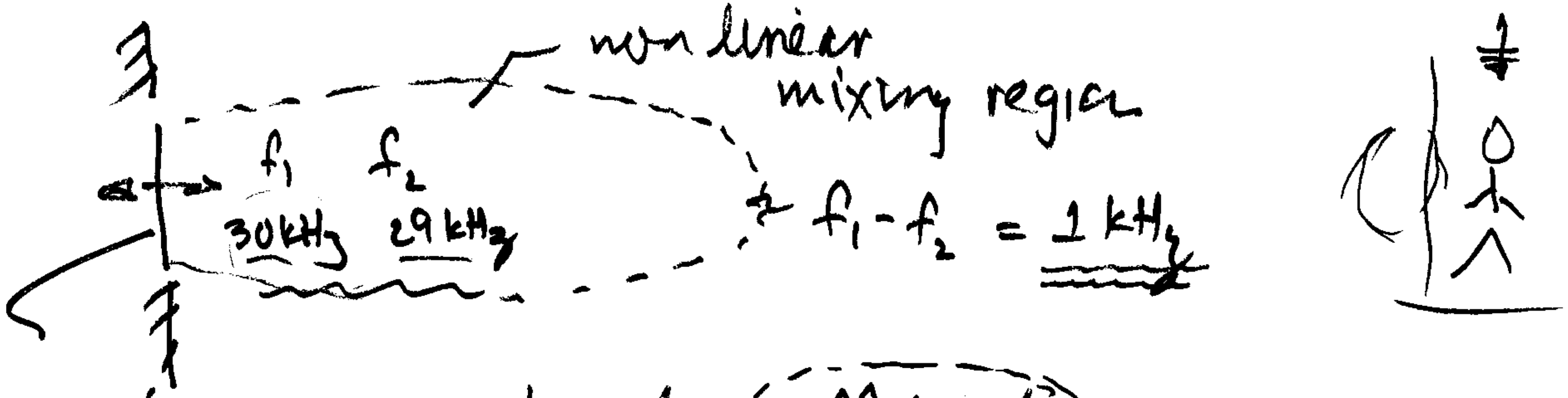
Extended Sources $ka \gg 1$

- piston in a baffle

$ka \ll 1$ omnidirectional

$ka \gg 1$ directional

Acoustic Flashlight - nonlinearity



force the source with f_1 & f_2 simultaneously

- highly inefficient
- dangerous

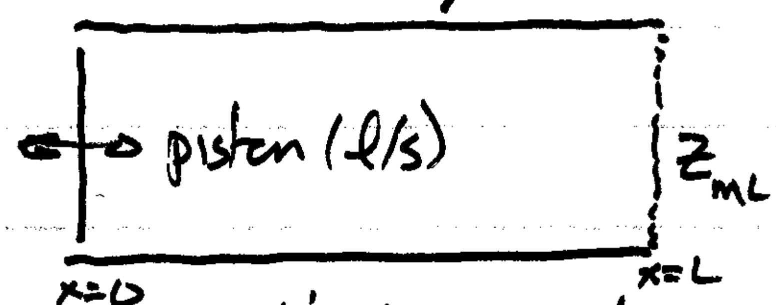
Thermophones

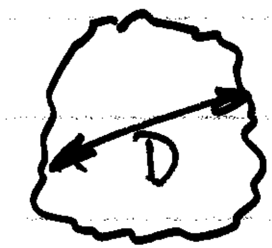
CNT

6.0 Pipes, Cavities & Waveguides

Chapter 10

constant cross-section ducts with hard walls





$D < \lambda/2$

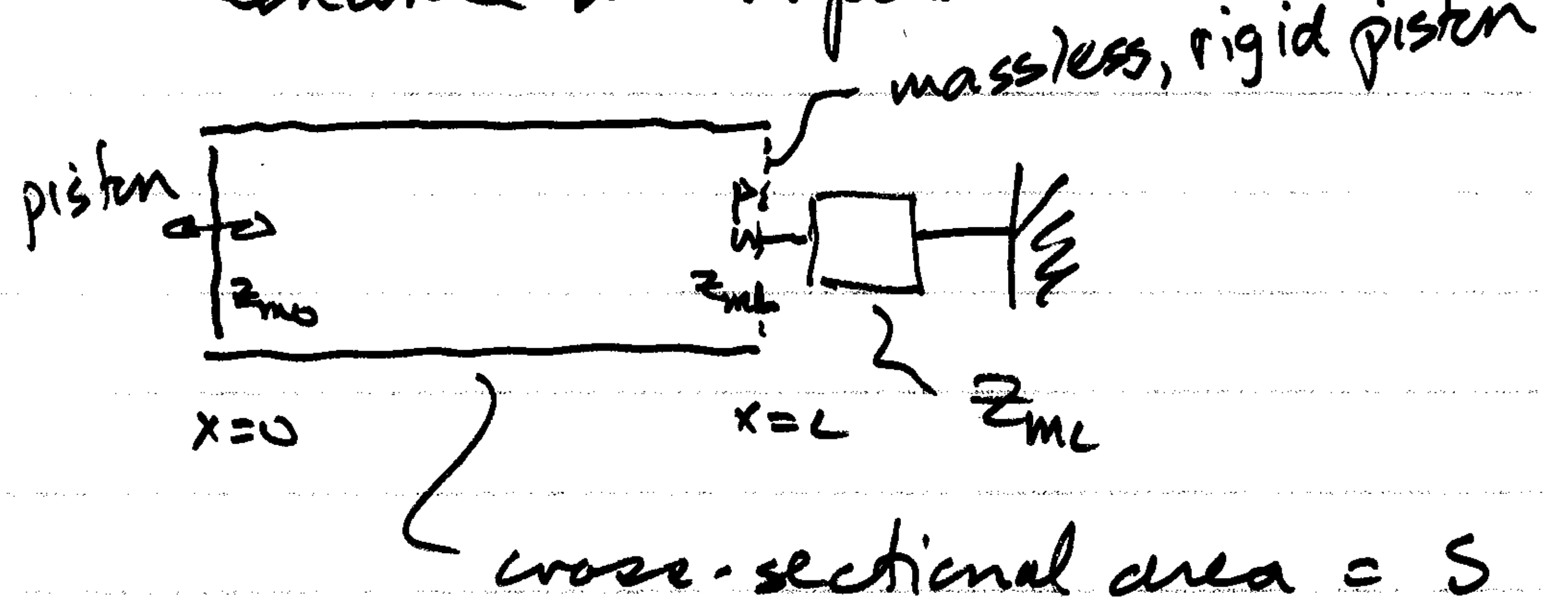
no higher order modes - only plane waves propagate

(i) what is the acoustic load on the source?

(ii) what are the resonant frequencies for the system

(iii) what's the sound power radiated by the source?

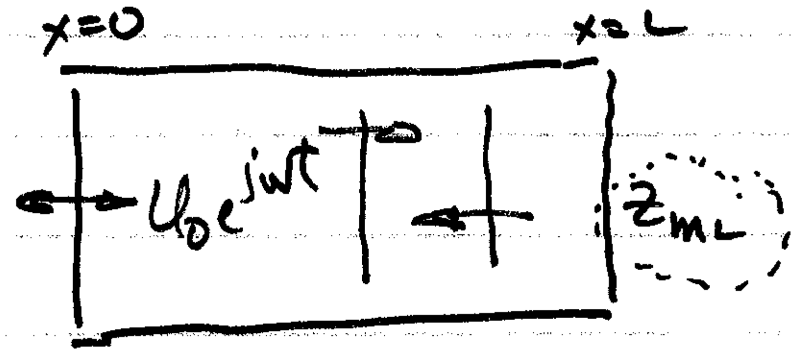
6.1 Resonance in Pipes



mechanical Impedance

$$Z_{mL} = \frac{F}{u}\Big|_{x=L} = \frac{pS}{u}\Big|_{x=L}$$

Objective: calculate the impedance experienced by the piston at $x=0$



$\tilde{p}(x) = \tilde{A} e^{-jkx} + \tilde{B} e^{+jkx}$

apply b.c.'s at $x=L$

$$\tilde{u}(x) = \frac{A}{\rho_0 c} e^{-jkx} - \frac{B}{\rho_0 c} e^{+jkx}$$

at $x = L$ $\left.\frac{S\tilde{p}}{\tilde{u}}\right|_{x=L} = Z_{mL}$

$$Z_{mL} = \left.\frac{S\tilde{p}}{\tilde{u}}\right|_{x=L} = S\rho_0 c \frac{Ae^{-jkL} + Be^{+jkL}}{Ae^{-jkL} - Be^{+jkL}} \qquad (1)$$

$$Z_{m0} = \left.\frac{S\hat{p}}{\tilde{u}}\right|_{x=0} = S\rho_0 c \frac{A+B}{A-B} \qquad (2)$$

$$Z_{m0} \neq Z_{mL}$$