GEORGIA INSTITUTE OF TECHNOLOGY

The George W. Woodruff
School of Mechanical Engineering

Ph.D. Qualifiers Exam - Fall Quarter 1998

Acoustics
EXAM AREA

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Assigned Number (DO NOT SIGN YOUR NAME)

- **Please sign your name on the back of this page—**

Please **print** your name here.

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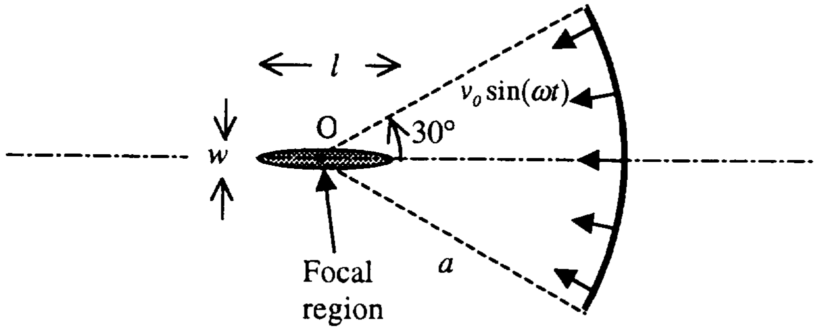


Focussed sources concentrate sound in a cigar shaped region (called the focal region) along the transducer axis. The length of the focal region (the "depth of focus") is l and its width is w. l and w are defined by points at which the sound pressure has decreased significantly (~ 3dB) from the peak value at the focal point. Alternatively, w can be defined as the diameter of the region in the focal plane through which most of the acoustic energy radiated by the projector passes.

A focussed transducer consists of a 30° spherical cap (sphere radius a) with normal surface velocity on the concave surface given by $v_0 \sin(\omega t)$ as shown above. Assuming that $ka >> 1$

a. Estimate the magnitude of the pressure at O.

b. Estimate the width of the focal region (w).

c. Estimate the length of the focal region (l) (depth of focus).

d. The peak pressure is not at O but somewhat to the right of it. Why?

Consider the sound field in a conical horn, as shown in the figure below. Assume that the horn diameter is small in comparison with both the acoustic wavelength and the length scale over which the cross-sectional area changes.

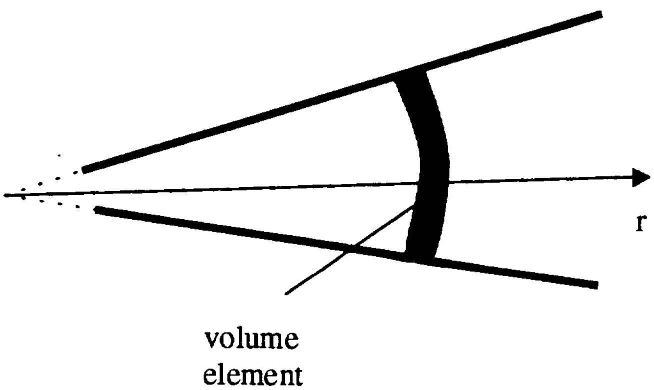
(a) Derive the conservation of mass and the linearised momentum equation for the control volume element shown in the figure. (This volume element is defined by spherical surfaces centered at the apex of the cone.) Hence show that the wave equation for propagation of sound in the horn is,

$$\frac{r^2}{c^2}\frac{\partial^2 p}{\partial t^2} = \frac{\partial}{\partial r}\left(r^2 \frac{\partial p}{\partial r}\right)$$

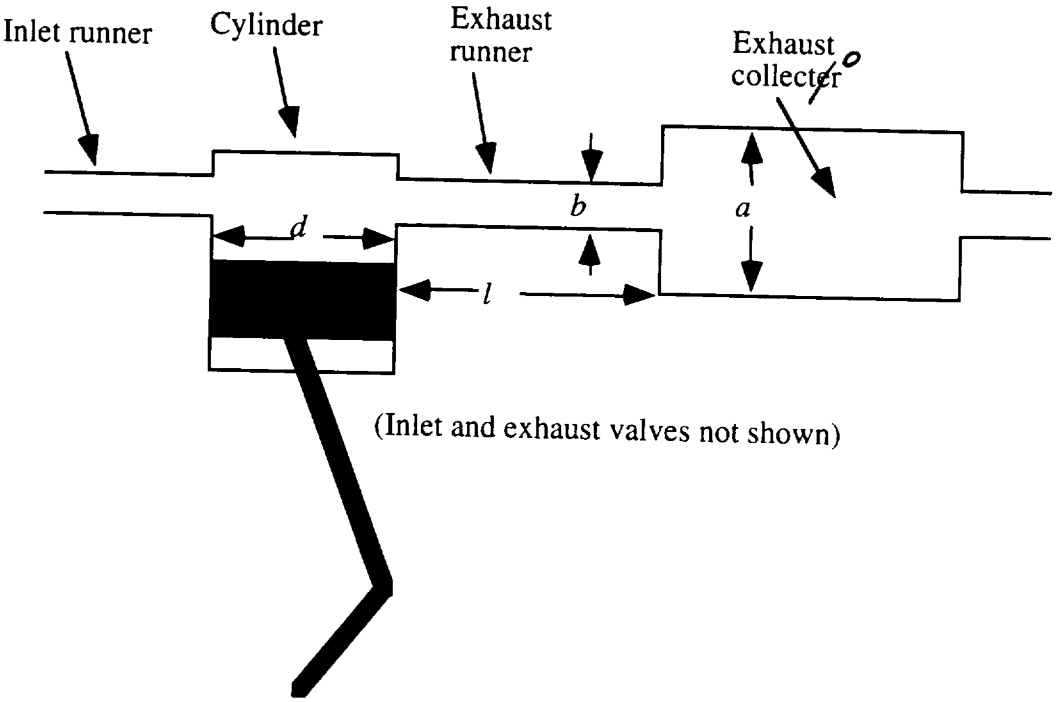
where p is the acoustic pressure and c is the speed of sound. What is the general solution of the above equation?

(b) A curved diaphragm vibrates at a frequency of 1 kHz in a conical horn and produces an outward propagating spherical wave. If the sound pressure level (SPL) at the point r=5 cm in the horn is 100 dB, what is the peak particle velocity there?

[The reference pressure for SPL in air is 20 μPa . At atmospheric pressure and room temperature the speed of sound and density of air are 340 m/s and 1.2 kg/m^3 .]



Consider the internal combustion engine exhaust system depicted below. The inlet and exhaust valves are not shown. One concept of internal combustion engine performance enhancement is termed 'exhaust gas tuning.' In this concept, the positive pressure pulse generated by the opening of the exhaust valve travels down the runner and is reflected back toward the cylinder with opposite sign by the expansion in cross-section at the inlet to the exhaust collector. The negative pulse arrives back at the cylinder while the exhaust valve is still open, and during a time that the inlet valve is open (called valve overlap). This negative pulse helps to scavenge the exhaust gases from the cylinder, and improves the engine's performance.



(Inlet and exhaust valves not shown)

Assume that the pulse propagation in the exhaust system may be modeled using a plane-wave assumption. Further, assume that the length of the exhaust collector is not important to the pulse reflection, and that only the change in cross-sectional area is significant. Ignore mean flow.

a) From consideration of reflected and transmitted waves at the interface between the exhaust runner and collector, determine the magnitude and sign of the reflected pressure pulse (the acoustic impedance of a pipe is $\rho_0 c/S$, where S is the cross-sectional area of the pipe, and $\rho_0 c$ has the usual interpretation).

b) "Exhaust tuning' is the selection of the proper exhaust runner length l such that the negative pulse arrives back at the cylinder at a specific time. For an engine turning at 3600 RPM, with the exhaust valve open for 90° of the rotation, estimate the runner length required such that the pulse arrives back at the cylinder 75° of rotation after the valve first opens. Note that the exhaust gas temperature may be up to 800 °C! Assume the fluid medium has the density, ratio of specific heats and gas constant as air.