GEORGIA INSTITUTE OF TECHNOLOGY

The George W. Woodruff
School of Mechanical Engineering

Ph.D. Qualifiers Exam - Fall Quarter 1997

Acoustics
EXAM AREA

____

Assigned Number **(DO NOT SIGN YOUR NAME)**

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

Please **print** your name here.

The Exam Committee will get a copy of this exam and will not be notified whose paper it is until it is graded.

Acoustics Qualifying Exam, Fall, 1997

Work all 3 problems. Show all of your work. Clearly state all assumptions.

Active noise control has received a great deal of research attention over the past 20 years. The most effective implimentation to date remains that of control of plane-wave noise in ducts. Consider the infinite duct of cross-sectional area S depicted below. A plane noise source is located at x=0, and a plane rol source is located at x=y. Consider the sources to be volume sources, of strength q_p and q_s.

a) Figure 1, below, depicts the pressure distribution in the duct immediately after the primary source has emmitted a rectangular sound pulse.

- If the secondary source is to completely cancel the downstream radiation, draw on Fig.2 the output of the secondary source at time t=L/c after the time represented in Fig. 1.
- Draw on Fig. 3 the total pressure distribution within the duct due to both the primary and secondary sources, at time t=L/c after the time represented in Fig. 1, and assuming complete downstream cancellation.

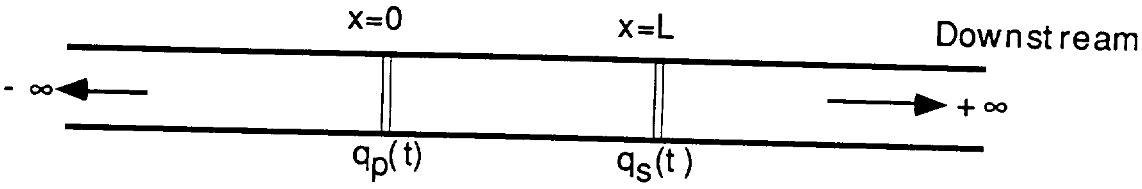


Fig. 1

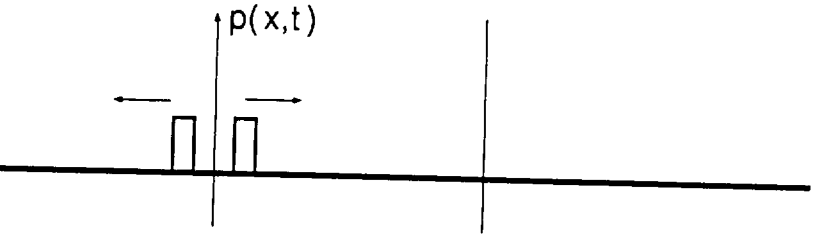


Fig. 2

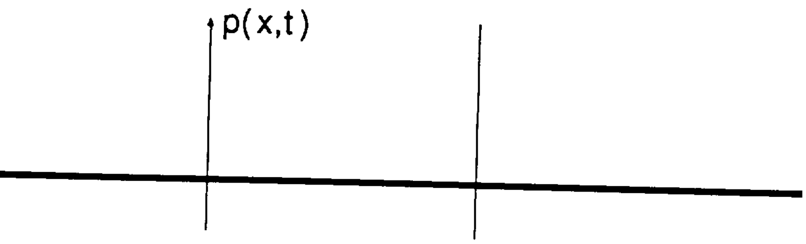
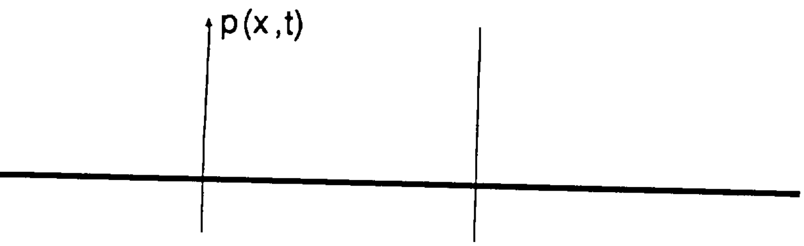


Fig. 3



1 b) For the exact same geometry, source position, etc, and with steady-state harmonic radiation with wavenumber k from the primary source:

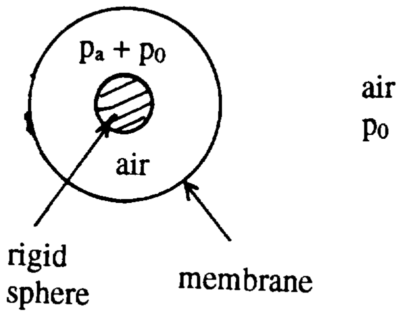
.at is the power output of the secondary source?

Determine an expression for the power output of the primary source, under the condition of complete downstream cancellation by the secondary source.

Under what conditions will upstream radiation be cancelled, as well?

2. A thin spherical membrane, of radius a, surrounds a rigid sphere of radius b, as shown in the diagram. The air inside the membrane is at a pressure $p_a + p_0$, where p_0 is the ambient pressure of the air outside. (Assume $p_a << p_0$). At time t=0 the membrane bursts.

Determine and sketch the acoustic pressure as a function of time for (1) a point in the far field, and (2) at r=b.



3a. The figures on the next page show a siren developed by R. J. Clark of Bell Labs during WWII. Air from a compressor is forced through six ports with a total area of 22 in^2. The ports are opened and closed by a rotary chopper which rotates at 4400 rpm. The *average* air flow through the siren is 2247 cubic feet per minute.

a. What is the fundamental frequency of the the siren? Would you expect it to have many harmonics? (15%)

b. The farfield pressure of any source can be written in the form

$$\left|\hat{p}_{farfield}(R,\theta,\phi)\right| = \frac{R_0}{R}\, p_0(\theta,\phi)$$

where R_0 i s a refence range usually taken to be 1 m. The *source level* of the source is defined as $20\log_{10}(p_0/p_{ref})$ with the reference pressure p_{ref} (in air) taken to be 20 μPa. Estimate what the source level of the siren in the direction of the siren axis would be **with the horn removed**. Justify any assumptions you make. (35%)

c. For a well designed horn, the axial acoustic velocity at the mouth of the horn will be re l to the velocity at the throat by

$$v_{mouth} = v_{throat}\sqrt{\frac{A_{throat}}{A_{mouth}}}$$

The mouth of the (combined) horn is a hexagon with a total surface area of 689 in^2. The effective throat area is the 22 in^2 total area of the six ports. Assuming that the mouth of the horn can be modeled as a piston in a rigid baffle, what is the farfield source level of the siren **on the axis** with the horn attached? **Note you do not have to evaluate any complicated integrals to get the answer!** (35%)

d. Would you expect the siren to be directional? Why? (5%)

e. Assuming that a sound pressure level of 80dBat the observer is necessary for the siren to an effective warning device in a typical noise environment, what is the approximate maximum effective range of the siren. (10%)

Constants you may (or may not) need:		
	density of air	1.2 kgm/m^3
	speed of sound in air	340 m/sec
	rest mass of a proton	1.6749286×10^{-27}kg

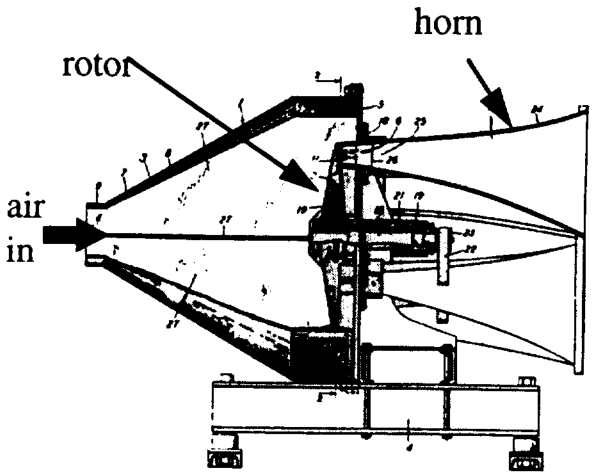


FIG. 2. A sketch showing a cross-sectional view of the siren. The rotor is seen edge-on.

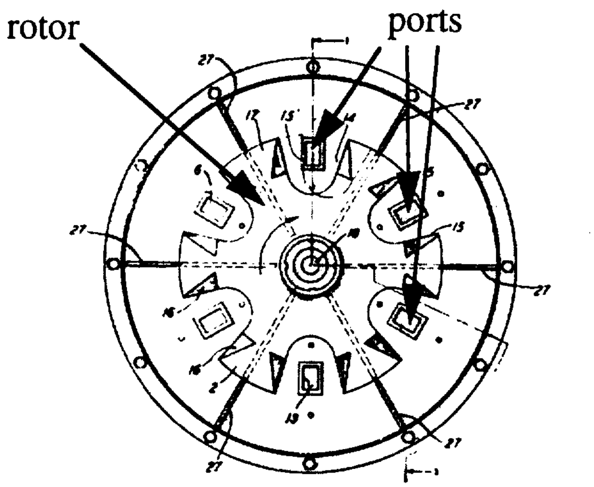
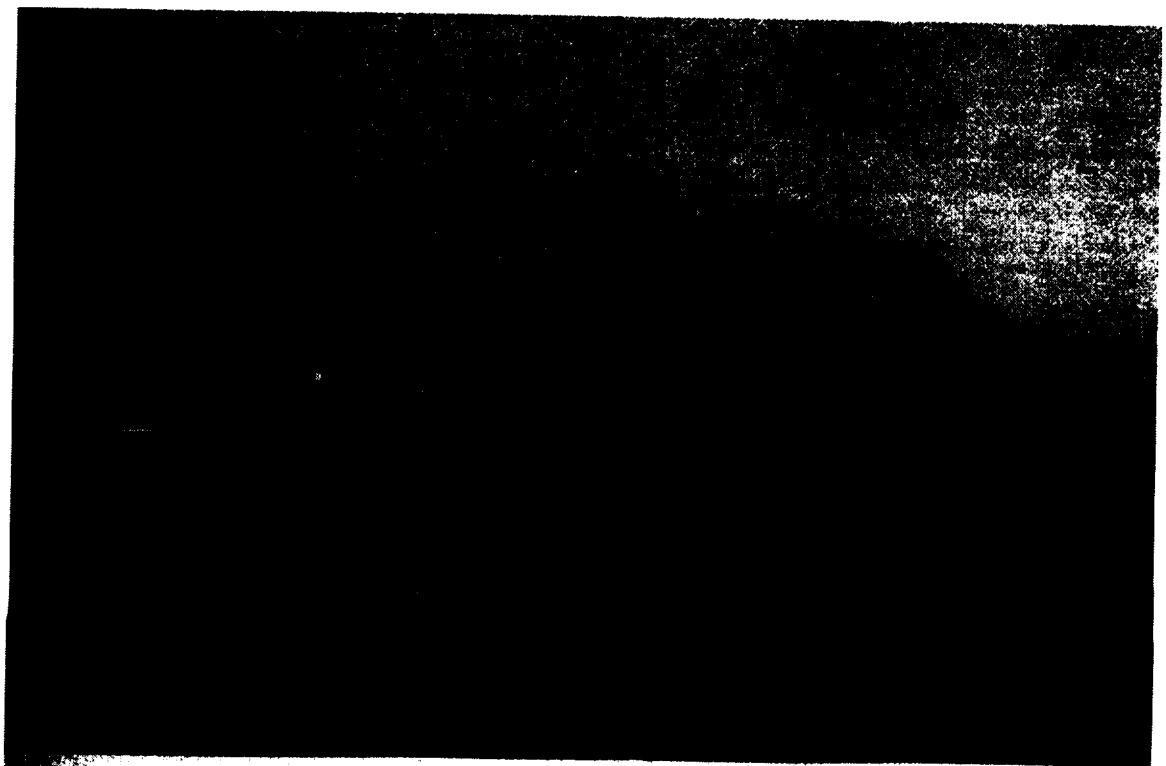


FIG. 3. A sketch showing the shape of the rotor and its position with respect to the six ports, one of which is indicated by the number 13.



View of the siren mounted on the truck. The intake filter and the compressor are shown to the right. The cone-shaped pressure chamber and the exponential horns on the left.