GEORGIA INSTITUTE OF TECHNOLOGY

The George W. Woodruff
School of Mechanical Engineering

Ph.D. Qualifiers Exam - Fall Semester 2000

Acoustics
EXAM AREA

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

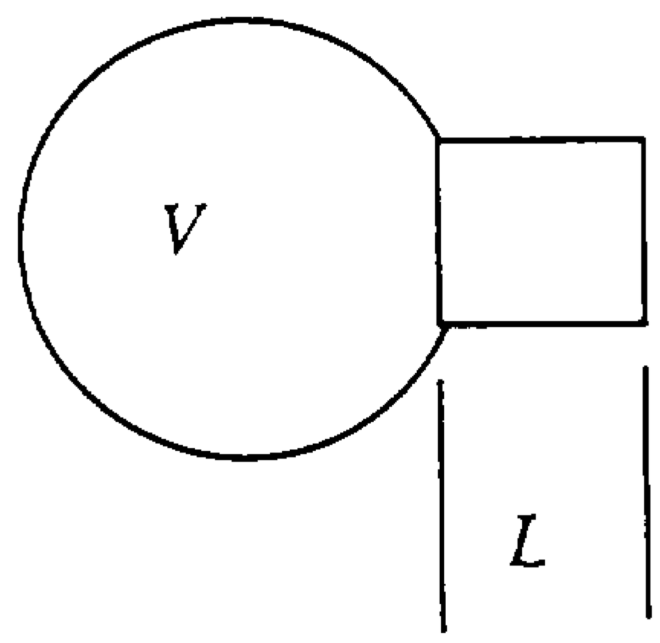
- **Please sign your name on the back of this page—**

Please **p r i n t** 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.

Aoustics Qualifying Examination
Fall 2000

Answer all parts of all questions.



1. A Helmholtz resonator is classical lumped-element acoustic device (anytime you've blown air across the end of a bottle and generated a tone, the bottle is acting as a Helmholtz resonator). Consider the resonator at left. It is a hollow sphere with volume V and a neck of length L . The neck has a cross section area A, and is open (i.e., air can flow into and out of the sphere through the neck).

Determine the resonance frequency of the Helmholtz resonator described above. The resonance frequency may be determined by modelling the system as a single-degree-of-freedom oscillator, where the oscillating fluid in the neck acts as the mass, and the fluid trapped in the sphere is the spring. You'll need to find the mass of the fluid in the neck, and the equivalent spring stiffness of the fluid in the volume.

If the neck is removed, leaving only a hole in the side of the sphere, resonant behavior will still be observed: what is acting as the mass in such a situation?

2. A homogeneous fluid with sound speed c and density ρ is moving with a constant velocity $\vec{\mathbf{v}}_0$. With respect to a stationary coordinate system:

a. What are the linearized Euler, mass conservation and state equations?
b. Eliminate particle velocity and acoustic density from these equations to arrive at a wave equation (for acoustic pressure) for this system.
c. Show that this wave equation has a plane wave solution of the form

$$p(\vec{\mathbf{r}},t) = f\left(t - \frac{\hat{\mathbf{n}} \cdot \vec{\mathbf{r}}}{c_{ph}}\right) \quad (1)$$

where f is an arbtrary function and $\hat{\mathbf{n}}$ is a unit vector normal to the wavefront.

d. What is c_{ph}?

e. If the acoustic pressure is given by Eq. 1 above, what is the acoustic particle velocity?

3. A time harmonic plane sound wave is incident on a thick layer of lossy material at an angle θ as shown in the figure. The material is so attenuating that it absorbs all the acoustic energy transmitted through the interface I and it has a surface impedance given by the relation

$$Z(\omega) = j\omega c_1 + c_2 + \frac{c_3}{j\omega}$$

where ω is the angular frequency of the incident plane waves.

a) Find the reflection coefficient R(ω,θ) and the fraction of the incident sound power absorbed.

b) Find the frequency at which the power absorption will be maximized. Comment on the dependence of the absorption on frequency, i.e. what happens when the frequency is very low (ω→0) or very high (ω→∞).

c) Find the incidence angle that will maximize the absorption at the frequency you found in part b.