M.E. Ph.D. Qualifier Exam
Fall Semester 1999

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GEORGIA INSTITUTE OF TECHNOLOGY

The George W. Woodruff
School of Mechanical Engineering

Ph.D. Qualifiers Exam - Fall Semester 1999

ACOUSTICS
EXAM AREA

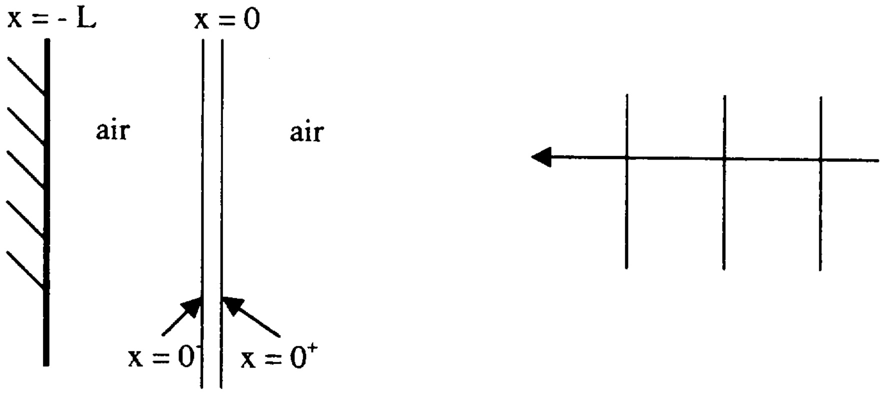
Assigned Number (DO NOT SIGN YOUR NAME)

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

ACOUSTICS – QUALIFYING EXAMINATION – FALL 99

Problem 1:

A harmonic plane wave, Pi $\exp[-i(\omega t - kx)]$, is normally incident on sheet of cloth that is hanging freely at a distance L in front of a rigid wall, as shown in the figure below. The cloth has a flow resistance R_f, defined as the ratio of the pressure drop between the front and the back of the cloth, divided by the air velocity through it. You may assume that the cloth is very thin compared to an acoustic wavelength, and that the cloth is sufficiently heavy that it does not move under the influence of the acoustic wave.



Derive an expression for the reflection coefficient. For a given frequency, $f=\omega/2\pi$, what is the distance L which minimizes the reflected energy? What is the advantage of this wall treatment compared with the one where the porous blanket is placed directly against the wall?

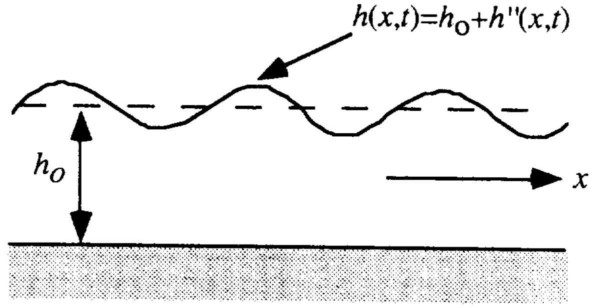
Problem 2:

Consider surface waves in shallow water (considered incompressible) as depicted in the figure below, where the mean depth h_o is small compared to the wavelength. Under such conditions, a valid assumption is that the pressure everywhere is approximately the hydrostatic pressure. Then, for small amplitude waves, $h' \ll h_o$, the appropriate versions of the equations for continuity and momentum are

$$\frac{\partial h}{\partial t} + h\frac{\partial u}{\partial x} = 0 \qquad (1)$$

and

$$\frac{\partial u}{\partial t} = -g\frac{\partial h}{\partial x} \qquad (2)$$



where g is the acceleration of gravity, u is the wave particle velocity in the x direction, and $h=h'+h_o$.

a) What is the wave equation in terms of u for this problem?

b) What is the general solution for propagation of shallow water waves? At what speed do shallow water waves propagate? Is the propagation speed of shallow water waves constant with water depth?

Problem 3:

A narrow, rectangular, thin plate is mounted in an infinite, plane, rigid baffle, as shown in the figure below. The plate is simply supported at both ends, and is driven into flexural vibration by an external force. The *normal displacement* of the plate is,

$$u(x,t) = u_0 \cos \frac{(n + 1/2)\pi x}{L} e^{-i\omega t}$$

The plate radiates sound into a semi-infinite fluid adjacent to the plate and the baffle.

Find the sound pressure at a point R_0, θ, ϕ in the farfield ($R_0 >> L$).

Outline the calculation of the sound power, **P,** radiated by the plate. (Describe the procedure for calculating **P** but omit detailed derivations). *Discuss qualitatively* how the magnitude of **P** varies as the frequency ω is increased from a value at which the wavelength in the fluid is greater than the wavelength of the plate vibrations to a value where the fluid wavelength is less than the plate wavelength.

[Assume that the width of the plate, w, is much less than the wavelength of sound in the adjacent
fluid. Note that the projection of x on R_0 is,

$$\vec{x}.\vec{n} = x \sin\theta \cos\phi$$

where n is a unit vector in the direction of R_0]