GEORGIA INSTITUTE OF TECHNOLOGY

The George W. Woodruff
School of Mechanical Engineering

Ph.D. Qualifiers Exam - Spring Semester 2003

Acoustics
EXAM AREA

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

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

Part I

Below its resonance frequency a thickness polarized piezoelectric sphere of radius a produces a radial displacement $d(t)$ which is proportional to the input voltage:

$$d(t) = \Gamma E(t)$$

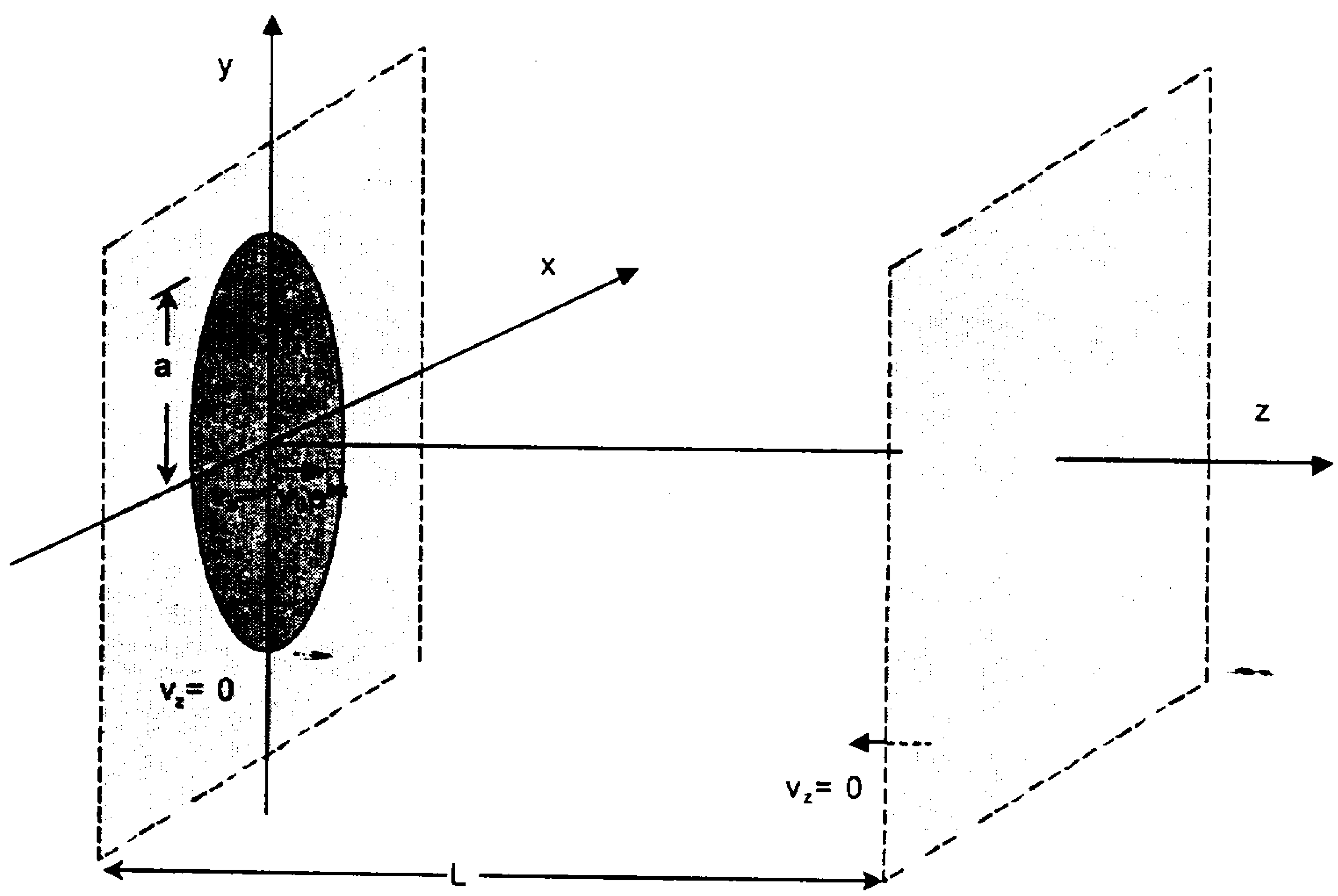
where Γ is a constant involving the piezoelectric properties and dimensions of the sphere.

a. Assuming a sinusoidal voltage drive, $E(t) = E_0 \cos(\omega t)$, what is the *magnitude* of the pressure (as a function of ω) at some farfield range R produced by such a transducer when radiating into an infinite medium with sound speed c and density ρ ? [Do not make any assumptions about the size of ω]

b. If $E(t)$ is some arbitrary function but the transducer is acoustically small [*i.e.* $ka << 1$ for the highest wavenumber of interest] what is the farfield pressure $p(R,t)$?

c. If $E(t)$ is some arbitrary function but the transducer is acoustically large [*i.e.* $ka >> 1$ for the smallest wavenumber of interest] what is the farfield pressure $p(R,t)$?

Part II



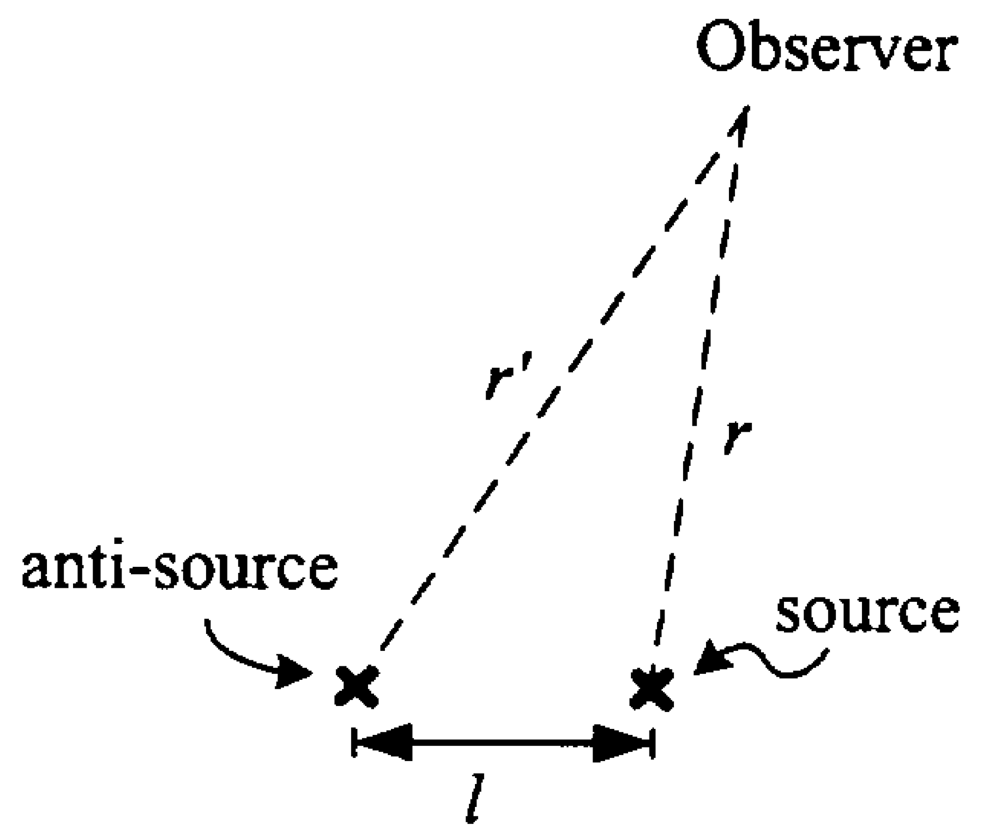
A circular piston of radius a is located in the plane $z = 0$. The piston oscillates in the z direction with a velocity given by $v_z = v_o e^{-i\omega t}$ as shown above. The remainder of the x-y plane is rigid and immovable. A second rigid immovable plane is located a z=L. As you recall, in the absence of the second plane the acoustic pressure on the z-axis would be given by

$$p(z) = \frac{v_o}{\rho c}\left[e^{ikz} - e^{ik\sqrt{z^2+a^2}}\right]$$

What is the acoustic pressure on the z-axis when the rigid plane at z=L is present?

A source radiating a pressure field $(p_0 / r)\sin\omega(t - r/c)$ is placed a distance l away from an 'anti-source' which generates a pressure $-(p_0 / r')\sin\omega(t - r'/c)$ at a distance r' away as shown in the figure below.

a) Calculate the acoustic power radiated by this double source combination. You can assume that the observer is far away from the sources, i.e. $l / r << 1$.
b) Compare your result with the power that would be radiated by each source in isolation, especially in the limits of very small and very large values of l. Comment on the differences, if there are any.



Problem 3

A semi-infinite fluid 1 overlays fluid layer 2 whose depth is H. The sound speeds satisfy $c_2 < c_1$, and the respective densities are ρ_1 and ρ_2. The floor is composed of a locally reacting material having specific impedance ξ. A plane wave at frequency ω in medium 1 is obliquely incident at angle θ_1 on the interface between the fluids.

(a) Derive a set of algebraic equations whose solution would yield the reflection coefficient R for medium 1.

(b) Prove whether or not there are there any sets of parameters ω, c_2, c_1, ρ_1, ρ_2, θ_1, H, and ξ for which $R = 1$.

(c) Is $R = 1$ the largest possible reflection coefficient? Justify your answer.