

RESERVE DESK

M.E. Ph.D. Qualifier Exam
Fall Semester 2002

GEORGIA INSTITUTE OF TECHNOLOGY

The George W. Woodruff
School of Mechanical Engineering

Ph.D. Qualifiers Exam - Fall Semester 2002

Acoustic

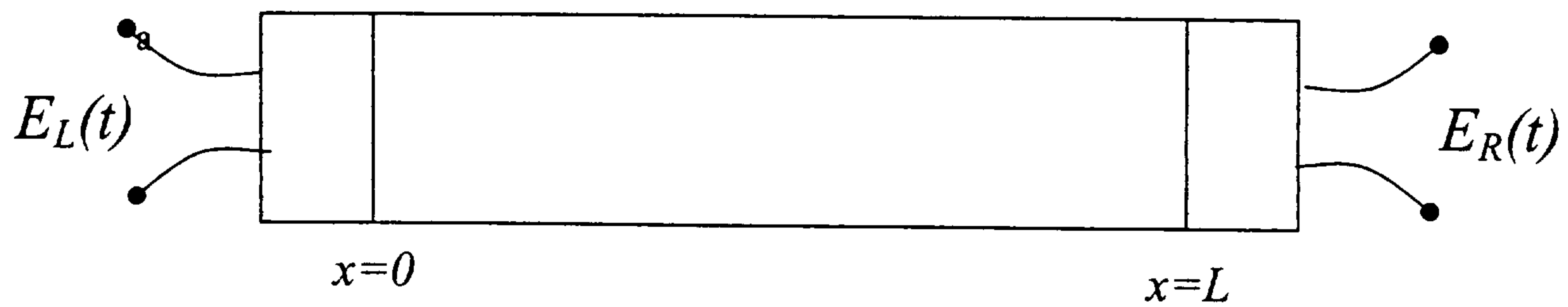
EXAM AREA

Assigned Number (DO NOT SIGN YOUR NAME)

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



A rigid walled pipe filled with a fluid with sound speed c and density ρ has identical ideal piston transducers on each end. One transducer has its face located at $x = 0$ and the other transducer has its face located at $x = L$. The transducers have the property that the displacement of the surface, $d(t)$ (defined as being positive when the displacement is toward the fluid) is exactly proportional to the input voltage:

$$d(t) = KE(t)$$

Assume that a voltage pulse of finite duration, $E_L(t)$, is applied to the transducer on the left.

1. With what voltage, $E_1(t)$, should the piston on the right be driven so that the pressure within the tube is identical to that which would occur if the transducer were replaced with a surface whose impedance is infinite (i.e. a rigid immovable boundary condition)
2. With what voltage, $E_2(t)$, should the piston on the right be driven so that there will be no reflected wave?
3. With what voltage, $E_3(t)$, should the piston on the right be driven so that the pressure within the tube is identical to that which would occur if the transducer were replaced with a surface whose impedance is zero (i.e. a pressure release boundary condition.).

The acoustic field generated by a point mass source situated at position \bar{x}_0 is governed by the inhomogeneous wave equation

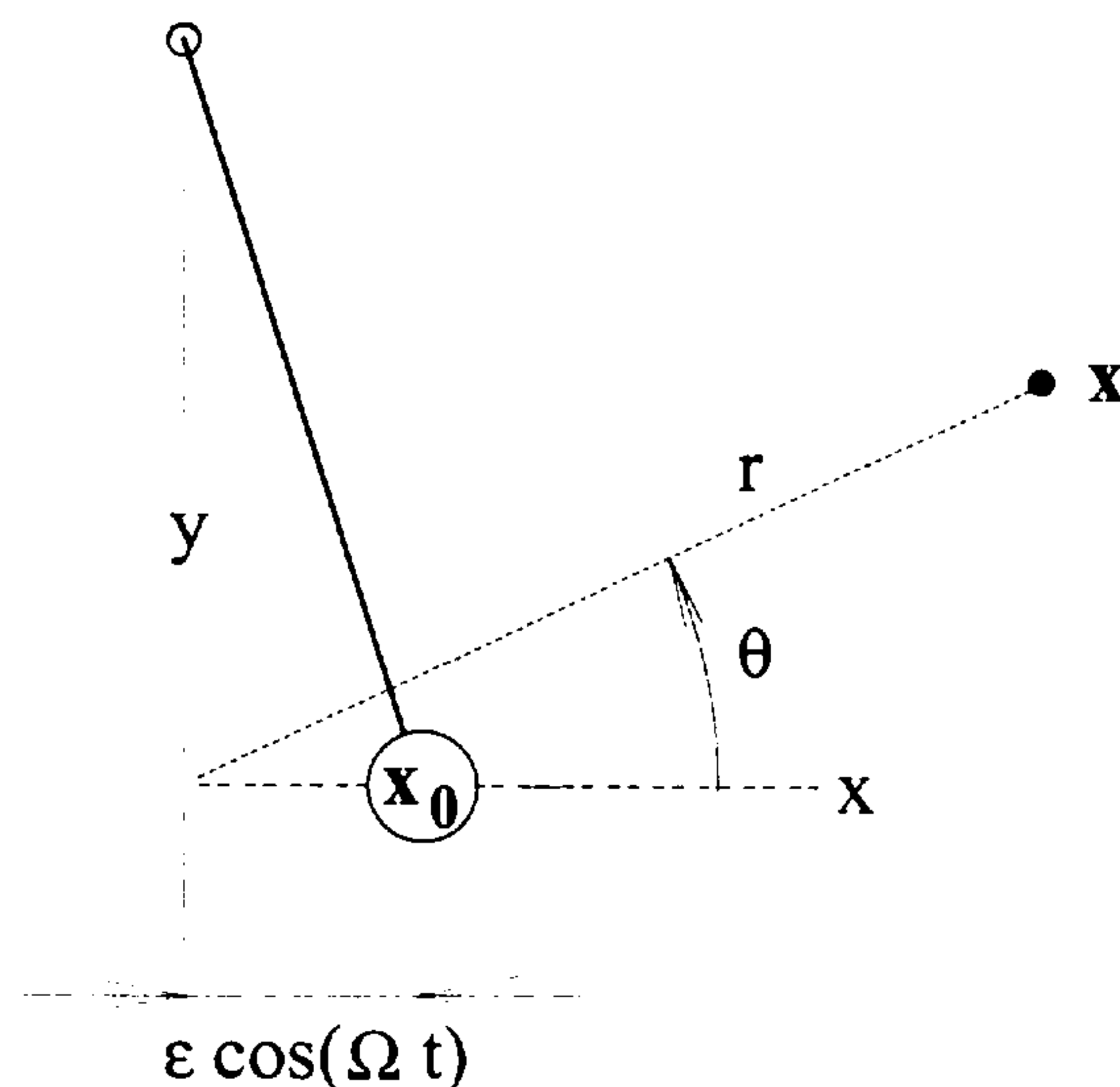
$$\nabla^2 p - \frac{1}{c^2} \frac{\partial^2 p}{\partial t^2} = -\rho_0 \dot{Q}(t) \delta(\bar{x} - \bar{x}_0)$$

where \bar{x} is the field point at which p is observed, and Q is the volume velocity. In the situation of interest, \bar{x}_0 is a known function of time.

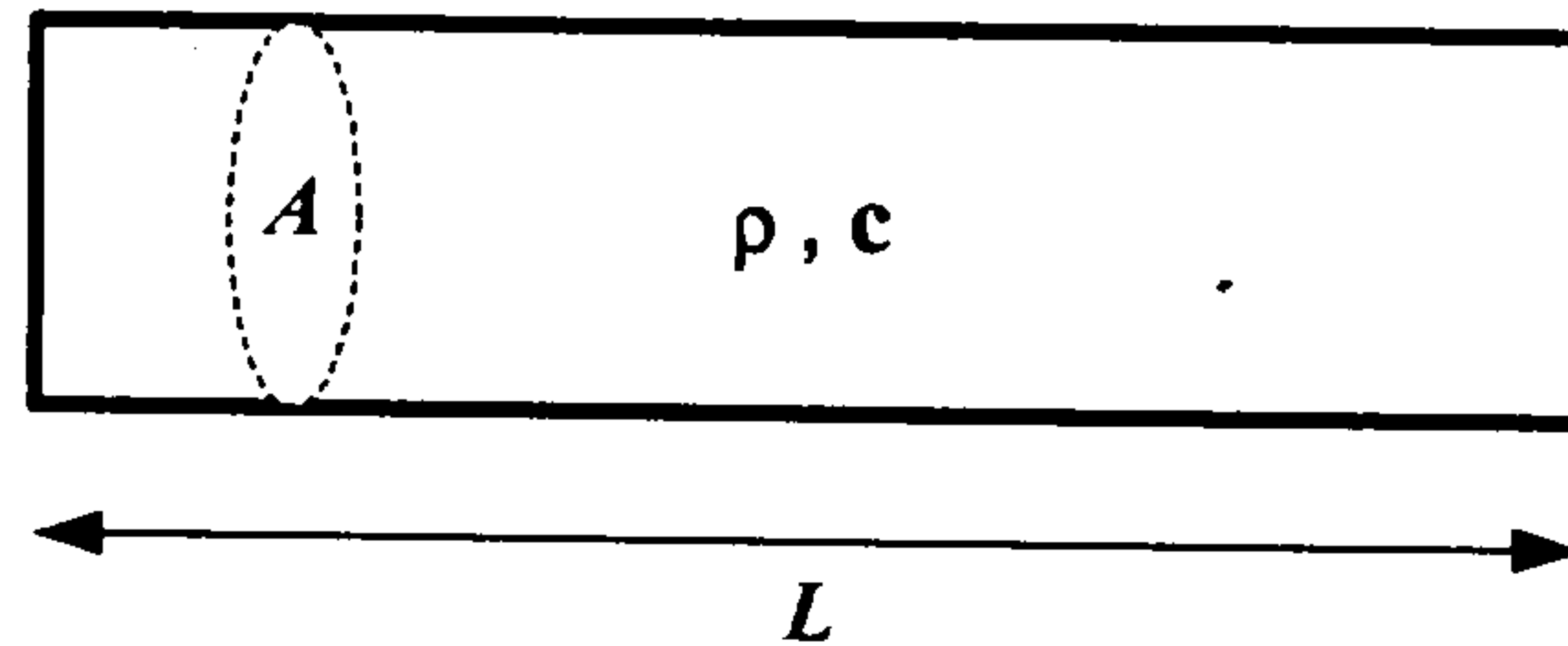
(a) What is the acoustic field that would result if \bar{x}_0 were fixed and $Q(t)$ were an arbitrary function?
 (b) What is the acoustic field that would result if \bar{x}_0 were fixed and $Q(t)$ were a harmonic function, $Q = \text{Re}[Q_0 \exp(i\omega t)]$?

(c) Explain why the answers to Parts (a) and (b) remain valid if \bar{x}_0 is a function of time.

(d) In the situation depicted below, a monopole is suspended from a cable that swings back and forth like a pendulum. The source strength varies harmonically at frequency ω , as described in part (b). The supporting cable is very long, so the location of the monopole may be considered to a vibration in the horizontal direction: $\bar{x}_0 = \varepsilon \cos(\Omega t) \bar{e}_x$, with $\Omega < \omega$. Also, the magnitude of the displacement, ε , is small compared to an acoustic wavelength, and all boundaries are sufficiently distant to consider the medium to be infinite in extent. Both ε and Ω are known values. Analyze the acoustic pressure that would be heard at a large distance from the monopole. This analysis may be approximate, but it should be carried out in sufficient accuracy to account for the fact that the signal depends on the polar angle θ , as well as the radial distance r measured from the mean position of the monopole. According to your analysis, what frequencies would be heard at an arbitrary field point?



a) Consider the rigid closed tube with cross-sectional area A and length L as shown below. Find the resonance frequencies of this structure assuming that the lateral dimensions are much smaller than the wavelengths of interest, i.e. plane pressure waves with associated volume velocity are propagating along the length of the tube. Plot the pressure and volume velocity distribution along the tube at the second resonance frequency.



b) Find the relation for the resonance frequencies when a hole is drilled at one end of the tube as shown in the figure below. The effective length of the opening is l' and the cross-sectional area is S . Show that at very low frequencies this relation results in the classical Helmholtz resonator formula. Assume that there is no radiation loss at the opening. Comment on the validity of the classical formula at higher frequencies.

