GEORGIA INSTITUTE OF TECHNOLOGY

The George W. Woodruff
School of Mechanical Engineering

Ph.D. Qualifiers Exam – Fall Semester 2006

ACOUSTICS

EXAM AREA

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

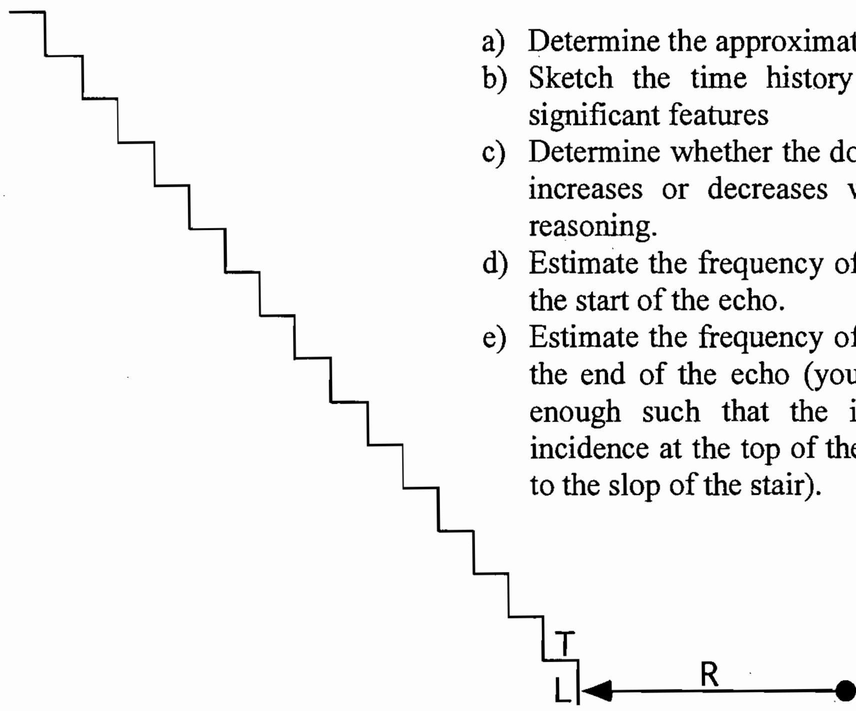
✱ Please sign your **name** on the back of this page —

PhD Qualifying Examination in Acoustics

Closed-book

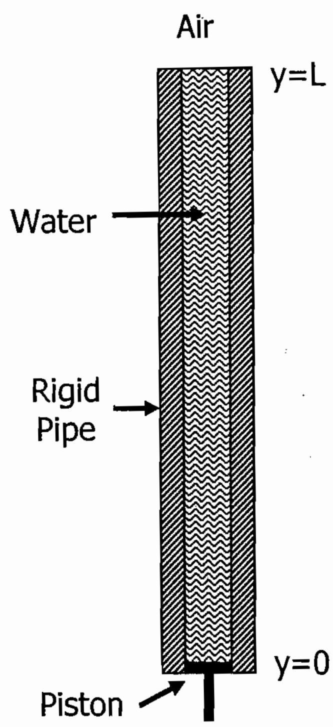
Answer all parts of all three questions

1) Consider a set of stairs. If an impulsive sound (such as a handclap) is produced at a point ***R*** in front of the stairs as depicted in the picture below, a "chirp" echo is produced. The chirp is of finite length, and of varying frequency content with time. The sound has been likened to that of the Quetzalcoatl bird. If there are *N* stairs in the set, each with a rise of *L* and tread depth *T*:



a) Determine the approximate duration of the echo.
b) Sketch the time history of the echo, and label its significant features
c) Determine whether the dominant frequency of the echo increases or decreases with time, and explain your reasoning.
d) Estimate the frequency of the fundamental harmonic at the start of the echo.
e) Estimate the frequency of the fundamental harmonic at the end of the echo (you may assume that *N* is large enough such that the incident wave is at grazing incidence at the top of the staircase, that is, it's parallel to the slop of the stair).

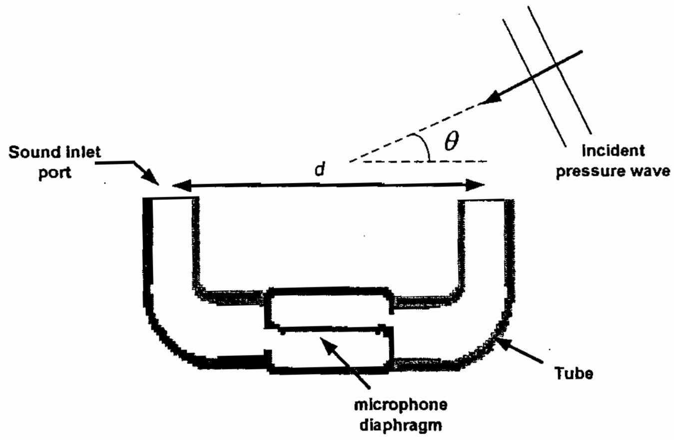
2)



Consider a water-filled rigid-walled pipe of length L with a piston at one end ($y=0$) and open to the air at the other end ($y=L$). At time $t = 0$ the piston starts moving upward at some small velocity v_o and continues to move with this velocity indefinitely. (Assume that the velocity is sufficiently small so that, for the purpose of establishing boundary conditions, the piston can always be considered to be located at $y = 0$).

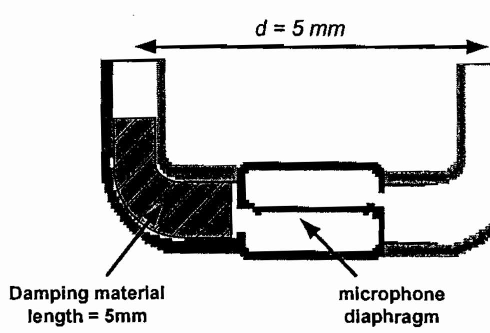
Plot the velocity at $y=L$ as a function of time from $t=0$ to $t = 12L/c$.

3) The figure below shows a directional microphone with two acoustic ports where the incident pressure wave is sampled at two points separated by a distance, *d*. The microphone diaphragm, which can be modeled as a simple spring, responds to the *pressure difference* between its front and back surfaces. The diaphragm displacement is converted to a signal using an electrical circuit.



a) Derive an expression for the as pressure difference across the diaphragm a function of incidence angle of the pressure wave, θ. The pressure wave is time harmonic at an angular frequency, ω. Plot the directivity pattern, i.e. magnitude of the microphone output versus incidence angle. You can assume that the distance between the ports is small as compared to wavelength and the propagation in the tubes is lossless.

b) Sometimes a damping material is placed in one of the tubes as shown below to introduce a frequency dependent phase shift which alters the directivity pattern of the microphone. For simplicity, assume that the losses in the damping region can be modeled by the slot flow resistance, R, the ratio of pressure drop per unit length to the average velocity over the cross section (unit: $N.s/m^4$). Derive the one dimensional wave equation for particle velocity in this region for the lowest propagation mode and obtain the propagation wavenumber for time harmonic waves.



c) Given the distance between sound ports and the length of material in the tube as above, determine the value of R so that the microphone response has a minimum at for sound incidence from the left side (i.e. $\theta = 180°$) at f = 1kHz. The properties of air are $\rho_o = 1.21$ kg/m^3, and $c_o = 343$ m/s.