# PhD Qualifying Examination in Acoustics

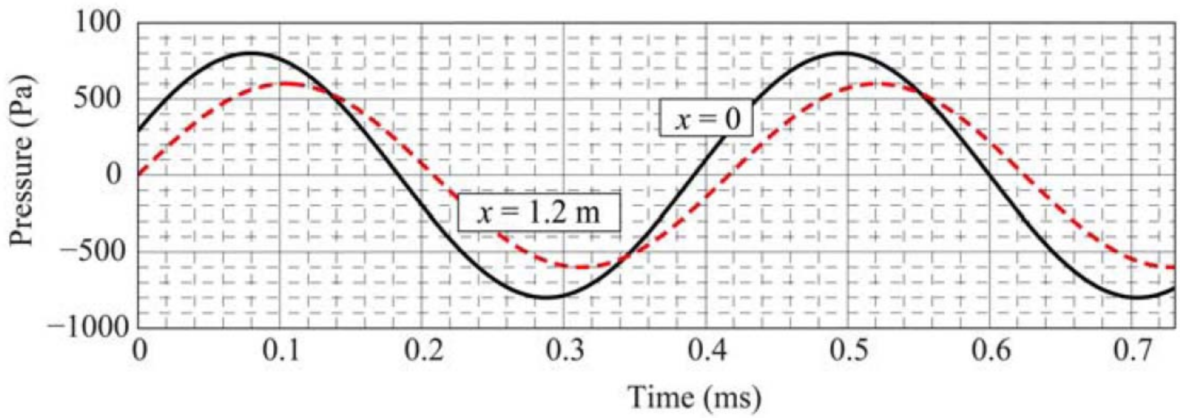
Two-hours, closed-book . Answer all parts of all three questions.

1) A harmonic signal is measured at x = 0 (solid line) and x= 1.2 m (dashed line) in a one-dimensional waveguide (see Fig. below). The speed of sound is 340 m/s, and the ambient density within the waveguide is 1.2 kg/$m^3$.

(a) Determine the frequency, wavenumber and complex amplitudes of the pair of oppositely traveling plane waves that compose this signal.

(b) Determine the amplitude of the particle velocity at x= 0 and x= 1.2 m.

c) Determine and sketch the RMS pressure as a function of propagation distance x.



2) A porous blanket is suspended in air at a distance $L$ from a rigid wall. The porous blanket is assumed to have a mass per unit area large enough such that it does not move under the influence of acoustic disturbances. With this assumption, the equation that relates the fluid velocity in front of the blanket, $v_{front}$, the fluid velocity in the opposite side of the blanket, $v_{back}$, to the fluid pressure in front of the blanket, $P_{front}$, and the fluid pressure on the opposite side of the blanket $P_{back}$, is the following:

$$v_{front} = v_{back} = \frac{1}{R_f}\left(P_{front} - P_{back}\right)$$

In response to a normally incident plane wave,

1. (4 points) Prove that the pressure reflection coefficient is given by (assuming a $e^{j\omega t}$ time dependence)

$$R = \frac{1 - \frac{\rho c}{R_f}(1 + j\cot kL)}{1 + \frac{\rho c}{R_f}(1 - j\cot kL)}$$

2. (3 points) Determine an expression for the specific acoustic impedance on a surface just in front of the blanket
3. (3 points) What is the fraction of the incident power that is absorbed?

If you cannot solve question 1, you can use the equation given in question 1 to solve questions 2 and 3.

3) The mean speed of sound in a real gas as a function of temperature may be represented as

$$c(T) = \sqrt{\gamma R T}\ . \qquad (1)$$

We know that there is a temperature perturbation in an acoustic wave which is in phase with the pressure disturbance. Therefore, the speed of sound is actually different for different parts of a wave, depending on the local pressure. For a *finite* amplitude wave (pressure no longer small compared to ambient), this local speed variation may be significant. The temperature perturbation within a wave is

$$T' = \left(\frac{\partial T}{\partial p}\right)_0 p' \qquad (2)$$

where

$$\left(\frac{\partial T}{\partial p}\right)_0 = \frac{\gamma - 1}{\gamma}\frac{1}{R\rho} \qquad (3)$$

and where R is the gas constant, $R = R_0/M$, with $R_0$ the universal gas constant and M the molecular weight of the gas, and p' is the acoustic pressure.

a) Obtain an expression for the local speed of sound within a plane wave as a function of the mean speed of sound $c_o$, $\gamma$, and acoustic particle velocity $u$ (Note: these should be the ONLY parameters in your result). Hint: you will need a Taylor series expansion of Eq. (1) about $T_o$, the plane wave impedance, and the relation $p=RT\rho$.

b) A more rigorous analysis than the one above yields the expression

$$c_{local} = c_o + u\frac{(\gamma + 1)}{2}$$

for the sound speed with respect to a fixed observer. Can you explain the difference between this expression and the one you derived above?

c) Comment on the physical significance of the results of parts A and B, particularly as it relates to long-range propagation. Assuming the temperature effect considered above is the only factor different from your prior knowledge of linear acoustics, does a finite amplitude wave's shape remain constant as it propagates?