ACOUSTICS QUALIFYING EXAM

FALL 2013

Work all three of the following problems.
Each problem will be graded on a 10-pt scale.

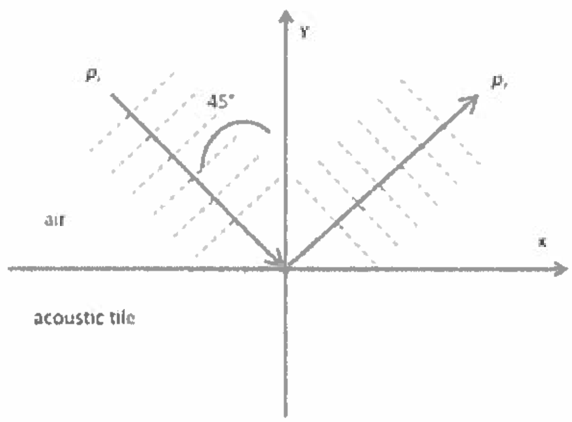
Problem 1

A plane wave of amplitude, A, in air is incident at an angle of 45° on a locally reacting sound-absorbing acoustic tile having a normal specific acoustic impedance of $\tilde{z}_n$. The total acoustic pressure just outside the surface is:

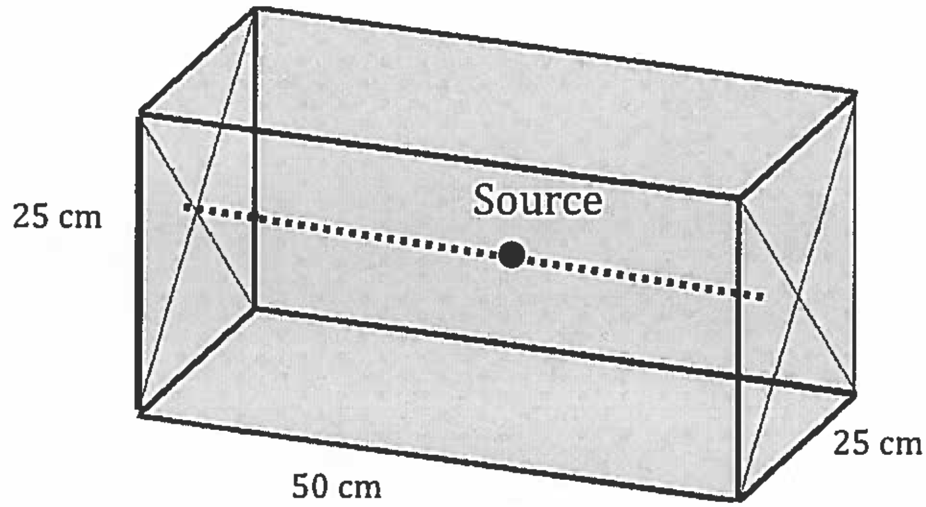
$$p_{total} = A\cos\left[\omega\left(t - \frac{x-y}{\sqrt{2}c}\right)\right] - 0.5A\sin\left[\omega\left(t - \frac{x+y}{\sqrt{2}c}\right)\right]$$

(a) Determine the pressure reflection coefficient at the interface. [4 pts]
(b) Determine $\tilde{z}_n$. [4 pts]
(c) What is the (sound power) absorption coefficient at the surface? [2 pts]

[Note: The answers to (a), (b) and (c) have real or complex numerical values.]



Problem 2



A 10-gallon fish tank has the dimensions shown above. The tank can be modeled by assuming the walls of the tank to be acoustically transparent, that is, as a water "brick" surrounded by air. The acoustic impedance of the air can be considered to be negligible compared to that of water. A projector is located in the exact center of the tank.

A. What are the three lowest unique resonance frequencies for this tank when driven by this source?

B. For frequencies much less than the lowest resonance frequency the pressure distribution within the tank is pretty much independent of frequency. Why?

C. The tank is excited by loudspeakers in the air such that the incident pressure on all six sides of the tank is uniform and equal to $p_0 \sin \omega t$ with $\omega << \omega_{low}$ where ω_{low} is the lowest resonance frequency of the tank. Which of the following statements correctly describes the field within the tank:

  a. The field is uniform and equal to p_0.
  b. The field is uniform and equal to $2p_0$.
  c. The field is uniform and equal to 0.
  d. The field looks like the first mode.
  e. None of the above

D. **Explain your reason for choosing your answer for part C.**

Problem 3

Consider harmonic plane wave propagation in the x-direction in a fluid having constant sound speed *c*, and average density that increases exponentially in the x-direction

$\rho = \rho_o e^{+x/L}$ and satisfying the following wave equation $\rho \nabla \cdot \left(\frac{1}{\rho} \nabla p \right) - \frac{1}{c^2} \frac{\partial^2 p}{\partial t^2} = 0$

For the questions below, ω=radian frequency of the plane wave, and the wave number *k* is a constant but it may have both real and imaginary parts. Assume that $2\omega L/c>1$ for all of the following questions.

a) (3pts) If $\hat{p}(x,t) = \hat{A}\exp\{ikx - i\omega t\}$ represents an acoustic wave in this environment, determine the wavenumber *k* in terms of ω,c and *L*.

b) (1.5pts) Interpret the value(s) found for *k*. What directions do the acoustic waves go and what happens to their amplitude as they propagate? [if you have not complete part a), use $k=\mp a+ib$, with $a,b>0$.]

c) (1.5pts) What is the propagation speed of the pressure waves? Is faster or slower than *c* ?

d) (2pts) Compute the temporally-averaged intensity of the plane wave(s) given in in part (a) in terms of the parameters introduced in the problem (i.e., ω, c, *L*, ...). Be sure to specify the direction(s) of the intensity.

e) (2pts) Does the smooth density change examined here lead to any reflection of acoustic energy?