UNIVERSITY OF NOTRE DAME
DEPARTMENT OF AEROSPACE AND MECHANICAL ENGINEERING

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Introduction to Acoustics

Homework 7

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I. Consider a narrow tube extending from $x = 0$ to $x = L$ with both ends open, i.e., the boundary condition at each end is $p = 0$. Find the natural frequencies and the eigenfunctions describing the acoustic pressure in the tube.

II. A piston at the $x = 0$ end of a tube of length L and radius a is oscillating with the velocity

$$v = \hat{v}e^{i(kx-\omega t)}. \tag{1}$$

1. The specific acoustic impedance at the end $x = L$ is $\epsilon\rho c$, where ϵ is a small positive real number, i.e., $\epsilon << 1$. Give the approximate expression for the lowest resonance frequency and the peak average acoustic power output of the piston for frequencies in the vicinity of this resonance.
2. For a flanged duct at low frequency, $\lambda >> a$, the specific acoustic impedance at the end $x = L$ is given by

$$Z_L = \rho_0 c_0[\frac{1}{2}(ka)^2 - i\frac{8}{3\pi}ka]. \tag{2}$$

   Calculate the resonance frequencies and efficient length L_{eff} defined as the tube length if the $Z_L = 0$. Calculate the power radiated from the duct. Take a typical example of your choice to calculate the relevant quantities.
3. For an unflanged open duct at low frequency, $\lambda >> a$, the specific acoustic impedance at the end $x = L$ is given by

$$Z_L = rho_0 c_0[\frac{1}{4}(ka)^2 - i0.6ka]. \tag{3}$$

   Calculate the resonance frequencies and efficient length L_{eff} defined as the tube length if the $Z_L = 0$. Calculate the power radiated from the duct. Take a typical example of your choice to calculate the relevant quantities.