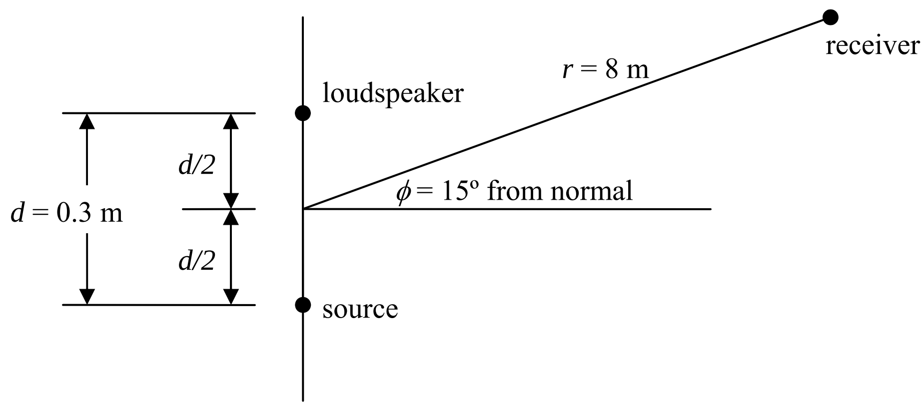
1. You wish to reduce a 100 Hz tonal noise emerging from simple source by placing an omnidirectional loudspeaker in plane with the source. The loudspeaker produces the same noise level as the source but is 180º out of phase. Assume the center of the loudspeaker is 0.3 m above the center of the source and a receiver is located as shown below (figure not to scale). The entire configuration is in air ($\rho = 1.21$ kg/m^3, c = 340 m/s).

a) By how much, in dB, will the sound pressure level at the receiver be reduced using your new configuration?

b) How much is the total power radiated reduced?

c) Where does the power go?



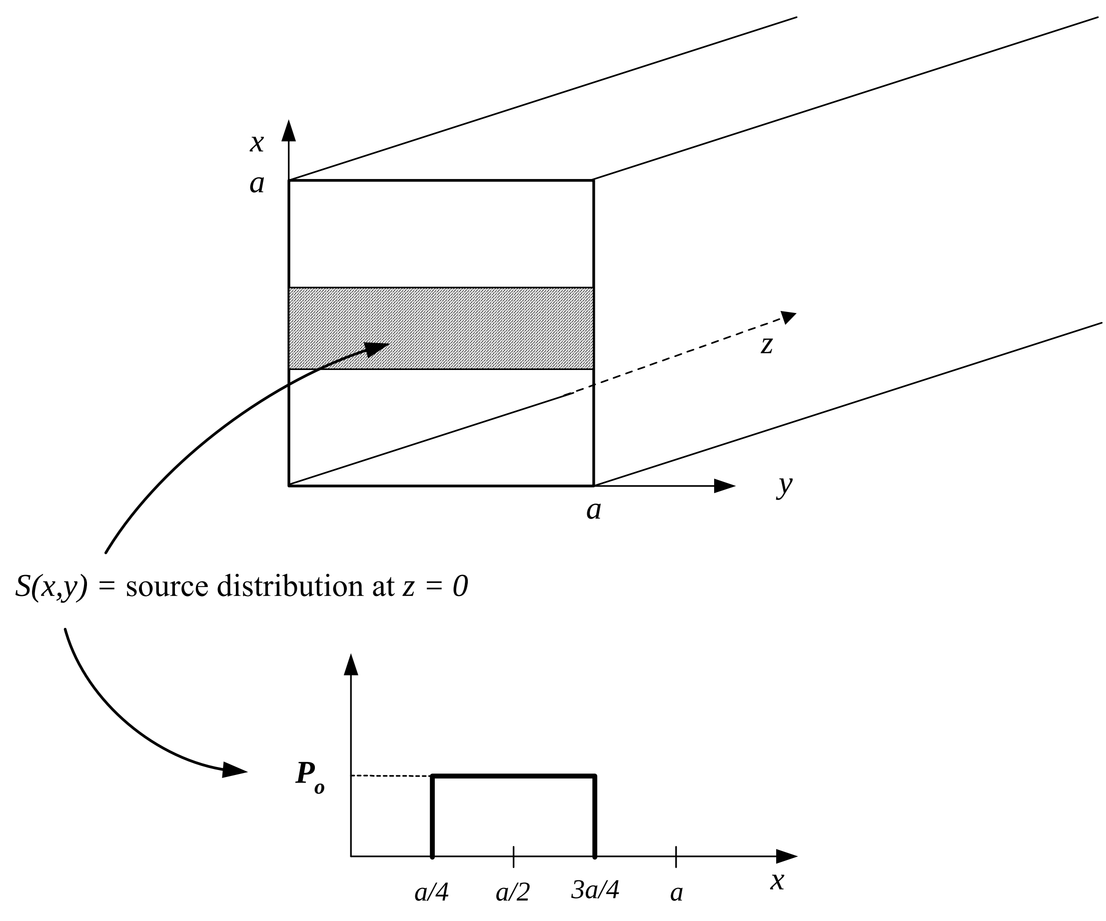
2. Consider the acoustic waveguide with a square cross section shown below. The side length of the rigid waveguide, a = 1m, and the waveguide is filled with air (ρ = 1.21 kg/m^3 c_o = 343 m/s). There is a time harmonic pressure source located at z = 0 driving the acoustic waves in the waveguide at f = 350 Hz with a spatial distribution

$P(x, y, z = 0; t) = S(x, y)\, e^{j\omega t}$, where $S(x,y)$, with no variation in y direction, is also shown below.

a) Which modes of this waveguide will be propagating when excited with this particular source? Clearly justify your answer with calculations.

b) Derive and plot the particle velocity field components at a large distance from the source, i.e. for large z. You can ignore the losses in the medium.

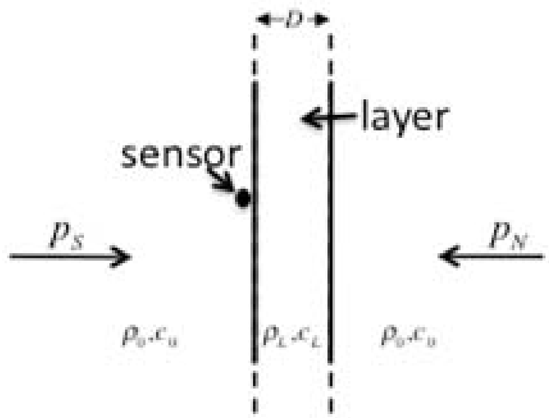
c) Find the total time averaged power radiated by this source.



3. For a certain underwater acoustic system, operating at frequency ω, sound coming from the left is considered to be "signal" and sound coming from the right is considered to be "noise". The signal to noise ratio is given by:

$$\frac{S}{N} = \frac{|p_S|}{|p_N|}$$

In an attempt to improve the S/N a layer of low acoustic impedance material of thickness *D*, is placed on the noise side of the sensor as shown below. It is assumed that the material and thickness of the layer have been chosen such that $|\sin(k_L D)| > .5$ and $\rho_0 c_0 >> 2\rho_L c_L$ for all frequencies of interest. Here k_L is the wavenumber in the layer, c_L and ρ_L are the density and sound speed of the layer and c_0 and ρ_0 are the density and sound speed of the surrounding water



a) Set up the equations that you would need to solve to determine the normal incidence pressure reflection and transmission coefficients for this system. (Do not solve them).

The complex normal incidence pressure reflection and transmission coefficients for the system are given by

$$T = \frac{2}{2\cos(k_L D) + i\left(\frac{\rho_L c_L}{\rho_0 c_0} + \frac{\rho_0 c_0}{\rho_L c_L}\right)\sin(k_L D)}$$

$$R = \frac{i\left(\frac{\rho_L c_L}{\rho_0 c_0} - \frac{\rho_0 c_0}{\rho_L c_L}\right)\sin(k_L D)}{2\cos(k_L D) + i\left(\frac{\rho_L c_L}{\rho_0 c_0} + \frac{\rho_0 c_0}{\rho_L c_L}\right)\sin(k_L D)}$$

b) If the sensor in the figure is a hydrophone (*i.e.* an acoustic pressure sensor) how is the S/N changed by adding the layer? Is it better or worse than without the layer?

c) If the sensor is, instead, an acoustic particle velocity sensor, how is the S/N changed by adding the layer? Is it better or worse than without the layer?