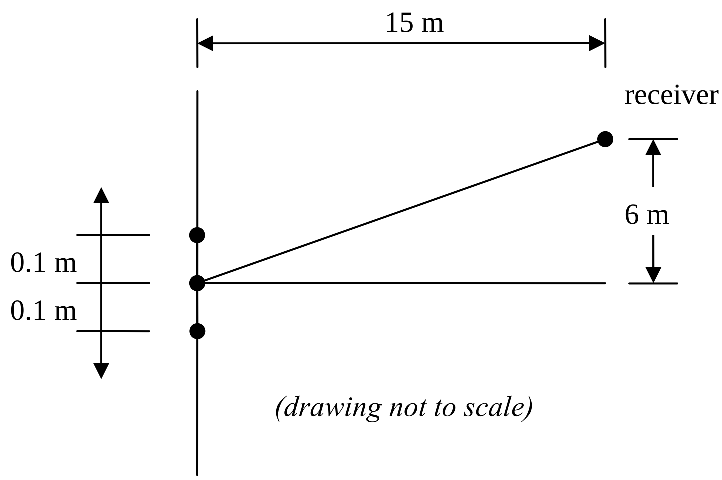
1. Three loudspeakers are mounted in line and flush with a rigid concrete floor of a hemi-anechoic space. The center speaker in free space radiates 2 watts, and the two outer speakers in free space each radiate 0.5 W of sound. It can be assumed that all three speakers are very small compared with the wavelength of sound they radiate, and air absorption & meteorological effects are negligible. The medium is air with c = 343 m/s, ρ_0 = 1.206 kg/m^3, and p_{ref} = 20 μPa. For the configuration shown below, calculate the expected sound pressure level (L_P) at receiver R (also flush with the floor) for the two following cases:

a. All three speakers play a 250 Hz pure tone such that the center speaker is 180º out of phase with the 2 outer ones (which are in phase).
b. All three speakers play 250 Hz one third octave band random noise, driven by three separate random noise generators.
c. Does the difference in L_P from (a) to (b) make sense based on your knowledge of sound source configurations? Why or why not?



(drawing not to scale)

2. The speed of sound in water is $c_w = 1500 \; m/s$ and its density is $\rho_w = 1000 \, kg/m^3$. The corresponding values for air are $c_a = 340 \; m/s$ and $\rho_a = 1.2 \, kg/m^3$. Bubbly mixtures of air and water often have sound speeds much lower than those of either water or air.

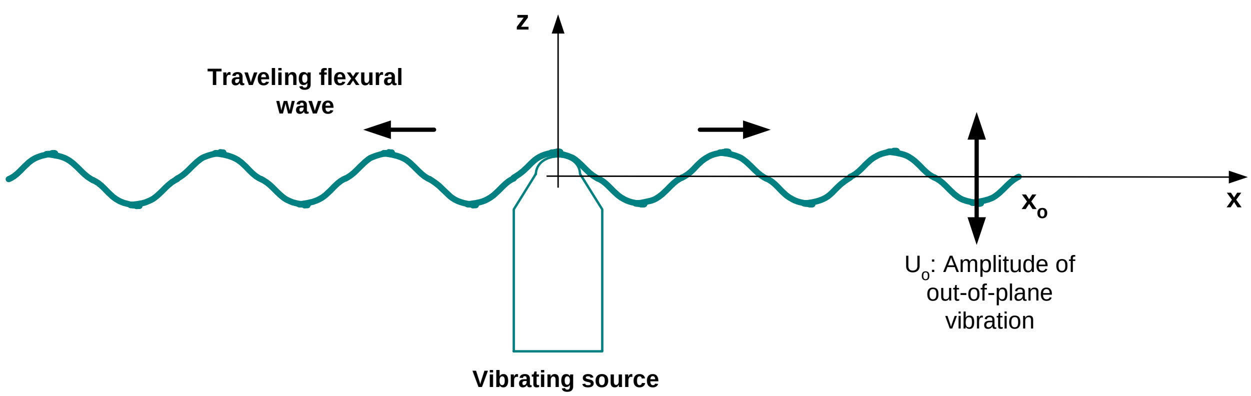
a. Explain in words why this happens. (30%)

b. Determine the sound speed for a bubbly air-water mixture that is 1% air by volume. (70%)

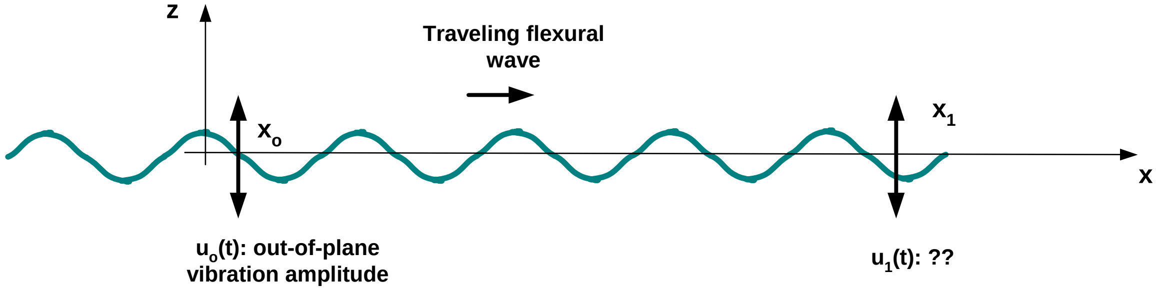
3. Consider the 1-D flexural waves generated by a contact transducer on a 3mm thick aluminum plate in air as shown below. A laser vibrometer is used to measure the out-of-plane displacement amplitude on the plate at any desired point.

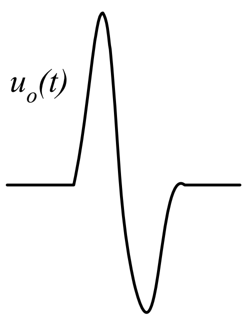
a) Assume that the excitation is sinusoidal at the frequency of 2 kHz and the vibrometer measures peak displacement amplitude of U_o at some distance x_o away from the source where the flexural wave is the dominant source of vibration. Determine and plot all relevant particle velocity components and pressure *in air* generated by this flexural wave for all z, and $x > x_o$. Clearly indicate any assumptions used in your calculations. You can assume that the plate is infinitely large in the lateral direction and ignore attenuation in the materials.

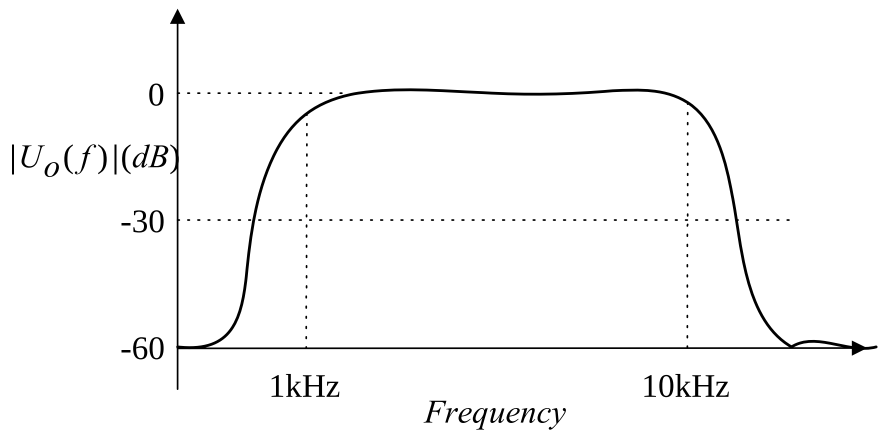
The properties of air are $\rho_{air} = 1.3$ kg/m^3, $c_{air} = 340$ m/s. The flexural wave speed in a thin plate is given by the dispersion relation, $c_{pl}(\omega) = (\frac{B}{h\rho_{Al}})^{1/4}\sqrt{\omega}$, where h is the plate thickness, $\rho_{Al} = 2700$ kg/m^3 is density of aluminum and ω is the angular frequency. The flexural rigidity of this plate, B, is given as 183.2 N.m.



b) Assume that the same plate is excited with a broad-band pulse. The time domain out-of-plane displacement signal on the plate measured at $x=x_o$, $u_o(t)$, and its frequency spectrum are given below (See next page). Qualitatively estimate and sketch the time domain displacement signal on the plate and its spectrum at another location along the propagation path, $x=x_1 >> x_o$.




$u_o(t)$


$|U_O(f)|(dB)$
0
-30
-60
1kHz
10kHz
Frequency