**UNIVERSITY OF NOTRE DAME**
**DEPARTMENT OF AEROSPACE AND MECHANICAL ENGINEERING**

Professor H.M. Atassi
113 Hessert Center
*Tel*: 631-5736
*Email*:atassi@nd.edu

AME-60663
Introduction to Acoustics

---

# Homework 3

## I. Spectral Density in White and Pink Noise

For sound in a frequency band $\Delta f$, the spectral density is defined as

$$I_f(f) = \lim_{(\Delta f)\to 0} \frac{I_b}{(\Delta f)}, \tag{1}$$

where $I_b$ is the average sound intensity in a frequency band $\Delta f$ centered at $f$. This definition allows us to define the average sound intensity in a finite frequency band $\{f_1, f_2\}$ by

$$I_b = \int_{f_1}^{f_2} I_f df. \tag{2}$$

1. For a one-octave band centered at $1000Hz$, find the lower and upper limits $f_1$ and $f_2$, respectively.
2. A white noise is an idealized model for sound with constant spectral density. The intensity of a one-octave band of sound centered at $1000Hz$ is equal to $85dB$. How does this intensity vary with the band center frequency $f_c$? What is the sound level of a one-octave band centered at $f_c = 250$.
3. A pink noise is an idealized model for sound with a spectral density $\propto 1/f$. If again the intensity of a one-octave band of sound centered at $1000Hz$ is equal to $85dB$, how does this intensity vary with the band center frequency $f_c$? What is the sound level of a one-octave band centered at $f_c = 250$.

## II. **Pulsating Spheres and Dipoles**

Consider two spheres of radius $a_0$. In a frame of reference where the $\{x_1, x_2\}$ axes are horizontal and the $x_3$ axis is vertical, the two spheres are centered at $\{0, 0, h\}$ and $\{0, 0, -h\}$. The two spheres have a pulsating harmonic motion with a circular frequency $\omega$ and a magnitude $a_1 << a_0$ and $a_1 << \lambda$, where $\lambda$ is the wavelength. For each of the following questions, consider the two cases:

(a) The two spheres are pulsating in phase.
(b) The two spheres are pulsating at $180^O$ out-of-phase.

1. Calculate the average pressure $\overline{p}$, intensity $\overline{I}$ and power $\overline{P}$ radiated from the two spheres at a various distance $r$ from the origin,i.e., $r \approx a_0$ and $r >> a_0$.
2. Consider the cases $a_1 = a_0/50$, $h = 2a_0$, $r = 2h, 4h, 10h, 50h, 100h$ and the frequencies $\{100Hz, 1000Hz, 10,000Hz\}$ plot the directivity of the pressure and intensity defined as $r\overline{p}$ and $r^2\overline{I}$, respectively. What is the effect of frequency?
3. Replace each sphere by a source of equal strength and examine the same issues as in the previous section. At what distance r and location $h$, the two spheres acoustic radiation is almost dipole-like. What is the effect of frequency?
4. Assess the source and dipole approximations.