EAE 298 Aeroacoustics, Fall Quarter 2016

Homework #4: Turbomachinery Noise
(Due Date: 12/06/2016 5pm)

Name : ________________________________

You are designing a new aircraft engine and analyzing acoustic propagation generated by a non-uniform flow with angle of attack interacting with rotating fans. You obtained flow fields from CFD for a one-sixth small scale of the engine. The radius for the small scale engine is 13 in and the hub radius is 3 in. CFD provides the velocity gust information as a function of its circumferential modes. The circumferential mode for acoustics can be expressed as $\mathrm{m} = \mathrm{nB} - \mathrm{kV}$ where B is the number of blades, V is the number of vanes, n stands for the harmonic of BPF and k is the integer (1, 2, 3….). You consider only positive k at this time (this is related the rotation direction of gust). The number of blades is 18. The number of vanes is considered to be 1 since there is no physical vanes but there is one revolution difference. The Mach number is 0.525 and the fan RPM is 8326.3042, the speed of sound is 13503.937009 in/s and the density is 1.4988E-5 slug/in^3. The dominant noise is generated at the 1^{st} BPF or n=1 in which the angular frequency is given as $\mathrm{RPM}\times\frac{2\pi}{60}\times B$. We are interested in the propagation through the inlet of the engine so that sound propagates to –z direction assuming the +z direction is in the flow direction.

1. [20 points] Determine the first five eigenvalues of acoustics for m=18, 17, 16, 15 or (k=1, 2, 3, 4) or (m,n)=(18,0), (18,1), (18,2), (18,3), (18,4), (17,0), (17,1), (17,2), (17,3), (17,4), (16,0), (16,1), (16,2), (16,3), (16,4), (15,0), (15,1), (15,2), (15,3), (15,4)

2. [20 points] Plot the five eigenfunctions (radial modes, n=0, 1, 2, 3, 4) for m=18, 17, 16, 15 or (k=1, 2, 3, 4) and verify n describes the number of zero crossings in the radial direction

3. [20 points] Determine the wavenumbers in the z direction for (m,n)=(18,0), (18,1), (18,2), (17,0), (17,1), (17,2), (16,0), (16,1), (16,2), (15,0), (15,1), (15,2). Indicate whether the mode is cut-on (propagating) or cut-off (exponentially decaying). Consider only the propagation in the –z direction. Exclude the exponentially growing solution and include only the propagating solutions or exponentially decaying solutions.

4. [30 points] The pressure distribution file at z=0 plane for m=18 or 1 BPF is provided. The first column is the dimensional radius [in], the second column the real part of the pressure [psi], and the third column is the imaginary part of the pressure [psi]. Using this boundary condition, compute the sound power level for (m,n)=(18,0), (18,1), (18,2). This noise is considered for blade self noise that is not associated with the gust response since k=0. Note that the z=0 plane is not the same as the engine inlet. Use the conversion for the unit for the sound power as follows: PWL (dB)=10*log10((Wmn))-10*log10(7.3756E-13)

5. [10 points] The imaginary value of $\mathrm{k_z}$ indicates the decay of sound pressure. Using the imaginary values of $\mathrm{k_z}$, compute sound power level at the engine inlet. The distance between z=0 plane and the engine inlet is 4 in.