

EAE 298 Aeroacoustics  
Fall Quarter 2016  
Homework #4

John Karasinski

December 4, 2016

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  $m = nB - kV$  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<sup>3</sup>. The dominant noise is generated at the 1st BPF or  $n=1$  in which the angular frequency is given as  $RPM \times \frac{2\pi}{60} \times B$ . 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.

### Problem 1. [20 points]

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

### Problem 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

### Problem 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.

### Problem 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:  $PWL (dB)=10*\log_{10}((W_{mn}))-10*\log_{10}(7.3756E-13)$