AE 710: Aeroacoustics (Spring 2021)

Course Instructor: Prof. Aniruddha Sinha
Contact Information: as@aero.iitb.ac.in
Office Hours: By appointment made by email at least 2 hours prior

Goals

Through this course you will gain an appreciation of aeroacoustics, i.e. flow-generated sound, as a component in holistic aerodynamic design. No prior exposure to classical acoustics is assumed. However, you will be expected to be familiar with the basics of fluid mechanics, e.g. the compressible Euler equations. By the end of the course, given a well-resolved flow field, you will be able to efficiently compute its sound field. Also, you will be in a position to delve into the current literature on aeroacoustics. The material will be mainly theoretical in nature, but the assignments will involve computation. Basic skill with at least one programming language is needed.

Course Content

1. Introduction:
   a. Background and definition of aeroacoustics
   b. Linearity of acoustics
2. Aspects of classical acoustic theory
   a. Governing equations for 1-D acoustics
   b. Governing equations for 3-D acoustics
   c. 1-D and spherically-symmetric acoustics in a medium at rest
   d. Kovasznay's decomposition of linearized fluid fluctuations
   e. Elements of solutions of Helmholtz equation
3. Acoustic fluctuations in non-uniform media (sheared flows)
4. Sources of aeroacoustic sound and their resultant fields
   a. Non-uniqueness of source identified from measured sound field
   b. Sound field of oscillating spheres (as elemental sources)
   c. Introduction to generalized functions and Green's theory for solution of partial differential equations, as required in acoustics
   d. Sound field due to monopole, dipole and quadrupole sources, their importance, and their relation with oscillating spheres
   e. Analysis of sound due to moving sources
   f. Reciprocal theorem in linear acoustics
5. Computational aeroacoustics: Spatial discretization, time discretization, finite difference solutions of linearized Euler, implementation of boundary conditions
6. Kirchhoff's formula of linear acoustics in the presence of surfaces
7. Lighthill's theory, and application to jet noise
8. Ffowcs-Williams and Hawkings' formulation of nonlinear acoustics in the presence of surfaces
9. Scattering of sound at an edge, as applicable to airfoil noise
10. Study of current literature on various topics of aeroacoustics

Primary references

- Goldstein, M. E., Aeroacoustics, McGraw-Hill, 1976

- Crighton, D. G., Basic principles of aerodynamic noise generation, Prog. Aerospace Sci., 16(1), 1975 pp. 31-96
- C. K. W. Tam. Computational aeroacoustics: a wave number approach. Cambridge Univ Press, 2012

Secondary reference
- Pierce, A. D., Acoustics, Acoustical Society of America, 1989
- Crighton, D. G., Dowling, A. P., Ffowcs Williams, J. E., Heckl, M. and Leppington, F. G., Modern methods in analytical acoustics, Springer, 1992
- Recent literature

Prerequisites
None; but exposure to compressible fluid dynamics and engineering mathematics will be very beneficial

Grading policy
Grades are based on the following break-up

60%: Homework assignments (6 assignments, 10% each)
10%: Quiz (Best 2 out of 3, 5% each)
20%: Mid-term exam
10%: Literature study report and presentation

- **No collaboration is allowed in assignments/reports; penalty is 100% of allocated marks for all works that appear as duplicates.**
- **Submission of assignments/reports *after* the assigned class (but within next scheduled class): penalty is 50% of allocated marks. Further delay incurs 100% penalty.**

Grades will be assigned by normalizing the score of every student with the highest score. Subsequently, the letter grades are assigned based on the score range given below:

AA:	100 – 90;	AB:	90 – 80;	BB:	80 – 70;	BC:	70 – 60
CC:	60 – 50;	CD:	50 – 40;	DD:	40 – 35;	FR:	Below 35

Note: The above system assumes that the overall score of at least one student is greater than or equal to 85. If none of the students in the class score marks greater than or equal to 85 then no one will be given an AA grade. In such a circumstance, the scores of all the students will be normalized according to the formula: score = (your_actual_score) x 90/85. Letter grades then will be assigned based on the split given above.

Attendance policy
Attendance is NOT compulsory. It is recognized that students may be unable to attend online classes on some occasion through no fault of theirs.

Audit policy
Overall pass marks (50%) in all assignments.