AE 710: Aeroacoustics (January-April 2024)

Course Instructor: Prof. Aniruddha Sinha
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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 and computational in nature, with the assignments involving significant amount of computation. Basic skill with at least one programming language is needed. There are no prerequisites for the course, apart from exposure to compressible fluid mechanics and engineering mathematics.

Course Content

Preliminaries:

1. Introduction
2. Fourier (spectral) analysis of (acoustic) signals

Propagation of sound waves:

3. 1-D acoustics in a medium at rest
4. 3-D acoustics in a general base flow
5. Elements of solutions of Helmholtz equation
6. Acoustic fluctuations in non-uniform media (sheared flows)

Computational aeroacoustics:

7. Spatial discretization of governing equations in wavenumber space
8. Time discretization
9. Finite difference solutions of linearized Euler equation, and implementation of boundary conditions

Fundamentals of classical acoustics:

10. Sources of aeroacoustic sound and their resultant fields
11. Sound field of oscillating spheres (as elemental sources)
12. Introduction to generalized functions; Green's theory for solution of partial differential equations, as required in acoustics
13. Sound field due to monopole, dipole and quadrupole sources, their importance, and their relation to oscillating spheres
14. Reciprocal theorem in linear acoustics
15. Kirchhoff's formula of linear acoustics in the presence of surfaces
16. Analysis of sound due to moving sources

Fundamentals of aeroacoustics:

17. Lighthill's theory, and application to jet noise
18. Ffowcs-Williams and Hawkings' formulation of nonlinear acoustics in the presence of surfaces
19. Scattering of sound at an edge, as applicable to airfoil noise

Study of current literature on various topics of aeroacoustics

References

Primary:

- 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:

- 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

Assessment scheme

10%: Weekly 5-min. quiz (10x1% – 17/1, 24/1, 31/1, 7/2, 14/2, 13/3, 20/3, 27/3, 3/4, 10/4)
10%: 30-minute quiz (2x5% – 9/2 & 22/3)
50%: Homework assignments (4 assignments, 10%, 10%, 20%, 10%)
10%: Literature study report and presentation
20%: Final exam (comprehensive)

- **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 a week): penalty is 50% of allocated marks. Further delay incurs 100% penalty.**

Grading policy

This course is NOT graded on a curve. Absolute grading is done, with some allowance for the toughness of the course. In particular, prior to awarding the final grade of a student, the total (raw) marks obtained by her will be normalized as follows

$$\text{Normalized marks} = \frac{\text{Actual (raw) marks}}{max(ClassMax, 90)} \times 100,$$

where $ClassMax$ is the maximum score achieved across the class. The following is the credit mapping scheme that will be used on the above rounded-up normalized marks:

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: Note that if the maximum raw score in the course is less than 90%, then 90 will be used in the normalization instead of the class maximum.

Attendance policy: Attendance is compulsory. If students do not attend at least 80% of the scheduled classes, then they will be awarded the DX grade (for Credit students; 'No Audit' grade for Audit students). ***Attendance will be recorded within the first 3 minutes of class.***

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