Gas Dynamics

Prof. Aniruddha Sinha

Autumn 2024

Syllabus

Introduction to Compressible Flows: Definition of compressible flow. Flow regimes: Speed and Mach number, Viscous and inviscid flow. Brief review of thermodynamics: Ideal gas, Internal energy and enthalpy, Laws of thermodynamics, Entropy, its calculations and isentropic relations. Aerodynamic forces on a body.

Integral Forms of Conservation Equations for Inviscid Flows: Brief review of philosophy and approach. Conservation of mass. Conservation of momentum. Conservation of energy.

One-Dimensional Flow: Introduction to 1-d flows. Speed of sound and Mach number. Some convenient flow parameters. Normal shock relations. Hugoniot equation. 1-d flow with heat addition. 1-d flow with friction.

Oblique Shock and Expansion Waves: Introduction to oblique shock waves. Oblique shock derivation: The $\theta - \beta - M$ relation, Supersonic flow over wedges and cones, Shock polar. Shock reflection from a solid surface. Shock-shock interactions: Pressure-deflection diagrams, Interaction of shocks of opposite families, Interaction of shocks of the same family, Mach reflection. Detached shock wave. Prandtl-Meyer expansion waves. Shock-expansion theory.

Quasi-One-Dimensional Flow: Introduction to quasi 1-d flow. Area-velocity relation. Convergent-divergent nozzles. Diffusers. Wave reflections from a free boundary.

Differential form of conservation equations for inviscid flows.

Unsteady Wave Motion: Introduction to unsteady wave motion. Moving normal shocks. Reflected shock wave. Wave propagation, acoustic and finite waves. Finite waves and characteristic lines. Incident and reflected expansion waves. Shock tube relations.

Hypersonic Flow: Characteristics of hypersonic flows. Hypersonic shock wave relations. Newtonian theory. Mach number independence. Hypersonic small-perturbation equations. Hypersonic similarity.

Textbooks

1. Anderson, Jr., J. D., Modern Compressible Flow: with Historical Perspective, 4th ed., McGraw Hill, 2021

References

1. Liepmann, H. W. and Roshko, A., Elements of Gasdynamics, Dover, 2002
2. Yahya, S. M., Fundamentals of Compressible Flow with Aircraft and Rocket Propulsion, 6^{th} ed., New Age International Publishers, 2018
3. Oosthuizen, P. H. and Carscallen, W. W., Introduction to Compressible Fluid Flow, 2^{nd} ed., CRC Press, 2015
4. Hodge, B. K. and Koenig, K., Compressible Fluid Dynamics with Personal Computer Applications, Pearson India, 2016
5. Zucker, R. D. and Biblarz, O., Fundamentals of Gas Dynamics, 3^{rd} ed., John Wiley and Sons, 2002

Course assessment scheme

The following is the tentative breakdown of weightage of each assessment component towards your final grade of 100%:

- Two quizzes – one before and the other after mid-semester – to be conducted on Wednesday afternoons (tentatively on 28^{th} August and 16^{th} October). Weight = 10 + 10 = 20%.
- Mid-semester exam. Weight = 20%.
- Two Python programming assignments, both in group mode. Weight = 10 + 10 = 20%.
- End-semester exam: Weight = 40%.

Class conduct policy

The students enrolled in this course must abide by the following policies:

1. Attendance in the scheduled class slots is mandatory. DX grade will be awarded to students who do not meet the minimum-80% attendance criterion.
2. Attendance will be taken within the first 3 minutes of class. If you are not present in the class within this, then you will be marked absence.
3. You will be required to submit two Python programming assignments using Google Colab. The assignments will be in group mode, so as to allow all of you to quickly learn programming/Python from each other. All students must conduct themselves with honesty in this matter. That is, by submitting these programming assignments, you will also be explicitly declaring that the corresponding work is your group's, and that you have not taken help from anyone else in doing it. Students may refer to their own notes as well as all material posted for this course for doing their work. Note that 'no help from others' rule also includes no help from online discussion fora, online resources, etc. However, you can always approach the teaching assistants or the instructor for help and guidance. Penalty for not abiding by this honour policy will be, at a minimum, a grade reduction. Per institute policy, severe cases of dishonesty can attract a fail grade too.

4. The submission deadline for the programming assignments will be hard. No excuse whatsoever will be entertained for late submission. You will have enough time from when the assignments are posted to their final deadline, and you must plan to submit well in time to avoid any unforeseen issues.
5. There is one teaching assistant (TA) for this course. You may contact him by email at all times. However, you have to realize that he is a student just like you, and thus will not be able to respond to your emails at all times. Please give him at least 12 hours to respond to any email. Do not email him at the last minute and expect immediate responses.

Credit mapping scheme

This course is NOT graded on a curve. Absolute grading is done, with some allowance for the toughness of the course, as apparent from the following scheme.

Prior to awarding the final grade, the total (raw) marks obtained by a student will be normalized as follows

$$Normalized\_marks = \text{Ceiling}\left(\frac{Actual\_marks}{\max(Class\_maximum, 90)} \times 100\right),$$

where $Class\_maximum$ is the maximum $Actual\_marks$ achieved across the class. The following is the credit mapping scheme that will be used on the above rounded-up normalized marks:

- AA: >= 90
- AB: >= 80
- BB: >= 70
- BC: >= 60
- CC: >= 50
- CD: >= 40
- DD: >= 30
- FR: < 30

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