Gas Dynamics

Prof. Aniruddha Sinha

Autumn 2025

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.

Sound and Normal Shock Waves: Introduction to frictionless adiabatic 1-d flows. Speed of sound and Mach number. Stagnation condition. Implication of Mach number revisited. Normal shock relations. Hugoniot equation.

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

One-Dimensional Flow with Heat Addition (Rayleigh flow).

One-Dimensional Adiabatic Flow with Friction (Fanno flow).

One-Dimensional Unsteady Wave Motion: Introduction to unsteady wave motion in 1-d. Moving and reflected normal shocks. Moving and reflected expansion waves. Shock tube.

Hypersonic Flow: Characteristics of hypersonic flows – high-temperature effects. Newtonian theory. Mach number independence.

Textbooks

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

2. Oosthuizen, P. H. and Carscallen, W. W., Introduction to Compressible Fluid Flow, 2nd ed., CRC Press, 2015

References

1. Rathakrishnan, E., Gas Dynamics, 6th ed., PHI Learning, 2017
2. Yahya, S. M., Fundamentals of Compressible Flow with Aircraft and Rocket Propulsion, 6th ed., New Age International Publishers, 2018
3. Zucker, R. D. and Biblarz, O., Fundamentals of Gas Dynamics, 3rd ed., John Wiley and Sons, 2002
4. Liepmann, H. W. and Roshko, A., Elements of Gasdynamics, Dover, 2002

Course assessment scheme

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

- One quiz on a Wednesday **afternoon** (tentatively on 20th August). Weight = 10%.
- Mid-semester exam. Weight = 20%.
- Two Python programming assignments, both in group mode. Weight = 15 + 15 = 30%.
- End-semester exam: Weight = 40%.

Class conduct policy

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

1. The course will be conducted in **flipped mode**. That is, reading assignments will be given prior to each class, and classes will be **only** used for discussion of concepts that you should have already read beforehand. Also, problems will be solved in class. No formal lecture will be delivered. The onus is on you to grasp the material and get their doubts clarified.
2. Attendance in the scheduled class slots is mandatory. DX grade will be awarded to students who do not meet the minimum-80% attendance criterion.
3. Attendance will be taken within the first 3 minutes of class. If you are not present in the class within this window, then you will be marked absent.
4. 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 implicitly 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 assistant 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.

5. 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.
6. There is one teaching assistant (TA) for this course. You may contact the TA by email at all times. However, you have to realize that the TA is a student just like you, and thus will not be able to respond to your emails at all times. Please give the TA 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: >= 81
- BB: >= 72
- BC: >= 63
- CC: >= 54
- CD: >= 45
- DD: >= 35
- FR: < 35

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.