ME 207 | FLUID DYNAMICS

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Tutors: Prof. Uddipta Ghosh and Mr. Ganeshkumar V

Lecture room: 10/201
Lecture slots: G1 (Tuesday 11:30 am to 12:50 pm) and K2 (Thursday 2:00 pm to 3:20 pm)

Tutorial rooms: 7/102 and 7/106
Tutorial slot: I2 (Wednesday, 2 pm to 3:20 pm)

Lab room: 10/101
Lab slot: K1 (Monday, 3:30 pm to 4:50 pm)

Teaching assistants: Mr. Sk Hossen Ali, Mr. Gourab Chakraborty, Mr. Inzamam Ahmad, Mr. Samujjwal Sarma, Mr. Akash KA

General description

This is a core course for B Tech students of Mechanical Engineering Department. Fluid Mechanics has been an integral part of Mechanical Engineering undergraduate programs across the globe over the past several decades. This "Fluid Dynamics" course is developed based on the classical "Fluid Mechanics" course, but it is given a modern orientation considering the recent scientific and technological advancements, development of new tools and methods to solve fluid flow problems, and ever-growing number of applications. The focus of the course will be on the fundamentals of fluid flow, but the course will be planned and conducted to equip students to solve real world problems. An integrated approach will therefore be adopted, in which students would learn the fundamentals via lectures and discussions, apply the fundamental concepts to solve problems in tutorial sessions, and do experiments and projects in laboratory sessions. As computations have become an integral part of all scientific and engineering endeavors, students will learn to use computers (and computational methods) to solve fluid flow problems.

Course contents

1. **Introduction**: History, and applications of fluid dynamics.
2. **Properties**: continuum approximation, Knudsen number, density, specific gravity, pressure, vapor pressure, compressibility, speed of sound, viscosity, surface tension.
3. **Fluid kinematics**: Lagrangian vs Eulerian descriptions, flow patterns and visualization, linear and volumetric strains, shear strain, and vorticity.
4. **Conservation laws and equations**: Reynolds transport theorem, integral and differential forms of conservation of mass, momentum (linear and angular), and energy; Navier-

Stokes equations and exact solutions. Bernoulli's equations, applications and its relation to conservation of energy.

5. **Dimensional analysis and modeling**: Dimensional analysis and similarity, method of repeating variables and the Buckingham Pi theorem, experimental testing and modeling.
6. **Flow regimes**: Reynolds number and qualitative description of different flow regimes: laminar vs turbulent flow, creeping flow, inviscid flow, irrotational flow, and boundary layers.
7. **Internal flow**: Boundary layer development, laminar and turbulent flow in pipes, major and minor losses, piping networks and pump rating.
8. **External flows**: concept of drag and lift, flow separation, friction and pressure drag, drag coefficients.
9. **Introduction to compressible flows**: Definition of compressible flow, Mach number and flow regimes, Quasi-1D isentropic flows, area-velocity relation, flow in nozzles and diffusers, choking, qualitative description of shock and expansion waves.
10. **Computational Fluid Dynamics (CFD)**: Solution of flow problems using CFD softwares.

Laboratory Experiments:

This course also includes a Laboratory component. The tentative list of experiments are as follows:

1. **Experiment with Pitot tube**: Stagnation pressure, Static pressure and the measurement of local flow velocity.
2. **Free and Forced Vortex:** Fluid kinematics
3. **Testing of Bernoulli's Equation**
4. **Impact of Liquid Jets:** Fluid Kinetics, Reynolds Transport theorem.
5. **Measurement of major and minor losses in pipe flows**
6. **The Reynolds' Apparatus:** Transition from laminar to turbulent flow
7. **Experimentation on flow meters.**

Learning outcomes:

Upon successfully completing the course, the student should be able to:

1. appreciate the importance and practical applications of fluid dynamics
2. demonstrate a strong understanding of key concepts in fluid dynamics
3. perform mass, momentum, and energy balances for flow systems encountered in real world
4. predict performance of an actual system by designing models that are similar and conducting experiments on these models
5. arrive at accurate estimates of the rating of pumps required for real-world piping systems.
6. solve real-world fluid flow problems to the extent possible using a computer
7. measure basic flow properties (such as velocity and pressure), examine fluid flows visually, and obtain data that is of engineering interest (such as losses, lift, and drag forces)

Texts and references

Text

1. Robert W. Fox, Alan T. McDonald, John W. Mitchell, *Fox and McDonald's Introduction to Fluid Mechanics*, Wiley Publishers, 10th edition, 2020.

2. Yunus A. Cengel and John M. Cimbala, *Fluid Mechanics: Fundamentals and Applications*, McGraw Hill, 4th edition, 2018.

References

3. Frank M. White, *Fluid Mechanics*, McGraw Hill, 8th edition, 2016

Grading
Homework assignments – 20 %
Lab reports -15 %
Project – 15 %
Examination I - 20 %
Examination II - 20 %
Attendance and class participation - 10 %

Attendance and class participation:
Fluid dynamics is a highly intuitive subject with lots of interesting applications. Class participation will help you stay on course and develop a better sense of understanding and appreciation of the subject. Attendance will be taken during all class sessions. Attendance and class participation make up 10 % of your total score. Your actual score will be based on the percentage of class sessions attended. Note that lectures/tutorials/lab sessions may also involve in-class exercises and these need to be completed satisfactorily to meet the attendance requirement.

In case of really genuine reasons such as medical/family emergency, a leave may be sanctioned by the instructor or concerned tutor on a case by case basis. However, permission needs to be taken beforehand for the leave to be approved. In case of illness, a doctor report also needs to be submitted. If the leave is approved, it will not negatively affect your attendance record. To seek prior approval/permission for leave, you are required to e-mail the concerned instructor or tutor in a single e-mail giving valid reasons and copying the designated teaching assistant on the same e-mail.

Homework assignment policy
Students can work together to solve homework assignments. However, each student must submit his/her own independent write up.

Conduct of Laboratory Sessions and Lab Reports:
(a) *Experiment hours*: Students are free to carry out the experiments at any time during the week, convenient to the TAs and our staff members.
(b) *Student Engagement:* The students will form groups with 4-5 members in each group. Each group has to submit a single report for each experiment. This means that the students need not submit the reports individually – one report per group for each experiment will be sufficient. The exact content of the report will be mentioned while assigning the experiments – also see point (d) below.

(c) *Engagement during Monday's lab hours:* The scheduled class hours would be spent discussing the tasks performed during the previous week. Every alternate week, a given group will have 5 minutes to present their experiments, observations and the interpretation of the results. This will be followed by a short Q&A session. Note that only half of the total number of groups will present their work every week. For instance, if there are a total of 14 groups numbered 1 to 14, then the first 7 groups will present their results during the first Monday's class and groups 8 – 14 will present their results during the second Monday's class, and so on.

(d) *Lab Test:* There will be a written lab test towards the end of the semester. The marks for this test will be part of the 15% weightage given to the "*Lab Reports*".

(e) *Important Note on lab reports:* Generally speaking, the lab report should include, (i) A schematic of the experimental set up along with a photograph; (ii) A brief outline of the experimental procedure; (iii) The experimental observations and error/uncertainty estimations; (iv) A proper interpretation of the recorded measurements. The reports must be submitted on time and any report submitted late will not be considered for grading.

(f) Students must quantify experimental uncertainty and possible errors very carefully, when they run the experiments. This may be achieved by repeating the experiments multiple times.

Late submission policy

Tutorial problems need to be submitted before the end of the respective tutorial session. *No late submission will be accepted*, except for genuine reasons such as medical or family emergency. Homework assignments and lab reports have to be submitted by the due date and time to avoid any late submission penalty. The late submission penalty is as follows:

a. For submissions past the due time on the due date, a penalty of 10 % will be applied.
b. For submission after midnight of the due date, a penalty of 25 % will be applied.
c. For submissions past 24 hours after the midnight of the due date, a penalty of 50 % will be applied and so forth.

Homework assignment format

Assignments are important means of learning during coursework. A clear organized solution of a problem is more important than the final numerical answer.

1. Begin each problem on a new page.
2. Clearly state the problem, listing the knowns and unknowns.
3. Use schematics and drawings wherever necessary.
4. List all assumptions and approximations.
5. Approach the problem from fundamentals and solve it in a systematic manner.
5. Pay more attention to the procedure than the final answer.
6. Write what you learnt from the problem.

Honor code

Students are expected to adhere to the IIT Gandhinagar honor code.