ME 643 | Aircraft and Rocket Propulsion

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Lecture room: 7/202

Lecture hours: P1 and P2 slots, 5-6:20 pm (Wednesday and Friday)

Teaching assistant: Mr. Prasanna Kulkarni

About the course:
This is a postgraduate course on aircraft and rocket propulsion. The course is designed to be a first course on propulsion with the intended audience being primarily postgraduate students and third and fourth year undergraduate students. While there are **no prerequisites** for this course and any student is welcome to register, it is desirable that the students registering for this course are familiar with the following subjects at the undergraduate level:

a. Thermodynamics
b. Calculus and Differential Equations
c. Computing

The course will have a strongly applied flavor. The fundamentals of thermal and fluid sciences would be applied to the design of aircraft and rocket engines. The course will also have a project component in which the students will work in groups to design an aircraft or rocket engine for a specific mission/application.

Course contents:

I. Introduction to Aircraft Propulsion

- Introduction and history of aircraft propulsion
- Air breathing engines: gas generator, turbojet, turbofan, turboprop, ramjet/ scramjet
- Aircraft engine performance parameters
- Engine operating limits
- Aircraft performance: performance equation, lift and drag.

II. Thermodynamics for Chemical Propulsion

- Quick review of thermodynamics
- Control volume approach for conservation equations
- Perfect gases, State equations, Mollier diagram
- Mixture of perfect gases, standard enthalpy and enthalpy of formation, adiabatic flame temperature, chemical equilibrium

III. Dynamics of Compressible Flows

- Compressible flow properties: stagnation temperature and pressure, compressible flow functions, mass flow rate, area ratio
- Velocity-area relationship for isentropic adiabatic flow

- 1D gas dynamics: differential control volume analysis
- Flow in a converging-diverging nozzle
- Overview of shocks and expansion waves

IV. Aircraft Gas Turbine Engines

- Generalized thrust equation
- Gas turbine engine components
- Brayton cycle

V. Parametric Cycle Analysis (PCA) of Air Breathing Engines

- Design inputs, steps of parametric cycle analysis, ideal cycle analysis assumptions
- Ideal and real ramjets
- Ideal and real turbojets (with and without afterburner)
- Ideal and real turbofans
- Ideal and real turboprop engines
- Engine performance analysis

VI. Rocket Propulsion

- History of rocket propulsion
- Thrust and impulse: static thrust, equivalent exhaust velocity, specific impulse
- Vehicle acceleration: Rocket equation, gravity losses and burning time, drag losses
- Rocket propulsion requirements and capabilities
- Staging and multi-stage rockets
- Rocket propulsion engines: thermal propulsion, chemical propulsion, nuclear propulsion, electrothermal propulsion, electric propulsion, electromagnetic propulsion, electrostatic propulsion, Electric power plants for space propulsion
- Types of rocket nozzles: conical nozzle, bell nozzle, plug nozzle
- Parameters for chemical rockets: mass flow rate, ideal thrust equation, characteristic velocity, nozzle exit velocity, thrust coefficient
- Rocket propellants: Liquid propellants, equilibrium composition, non- equilibrium expansion, solid propellants, combustion chambers, combustion characteristics, combustion instabilities

VII. Turbine Engine Components

- Inlets
- Nozzles
- Combustors
- Compressors
- Turbines

Learning outcomes

Upon successful completion of the course, students should be able to:

1. demonstrate strong understanding of mechanics and thermodynamics of propulsion
2. demonstrate strong understanding of different propulsion systems and their operating envelopes
3. analyze performance of aircraft and rocket engines and compute performance parameters
4. select and design a suitable propulsion system to meet mission requirements and goals
5. understand basic operation of engine components such as inlets, nozzles, combustors, compressors, and turbines

Texts and references

Text

1. Elements of Propulsion: Gas Turbines and Rockets by Jack D. Mattingly and Keith M. Boyer, Second edition, American Institute of Aeronautics and Astronautics, 2016.
2. Mechanics and Thermodynamics of Propulsion by Philip Hill and Carl Peterson, Addison-Wesleyl, 1992.

References

1. Rocket Propulsion Elements by George P. Sutton and Oscar Biblarz, 9th edition, John Wiley and Sons, 2016
2. Aerothermodynamics of Gas Turbine and Rocket Propulsion by Gordon Oates, AIAA Education Series, 1997.

Grading

Assignments - 30 %
Project - 20 %
Examination I - 25 %
Examination II - 25 %

Assignment policy

Students can work together to solve assignment problems. However, each student must submit own independent write up. Assignments 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.

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.