

HYPERSONICS

ENAS 425

Lecture : 3
Tutorial : 2
Practical : 1

Year : IV
Part : I

Course Objectives:

The objective of this course is to provide students with a comprehensive understanding of the rapidly evolving field of hypersonic technology and its emerging applications in civil and defense aerospace engineering. It emphasizes the historical evolution to the current state of the art, fundamental physical phenomena and major technological challenges associated with hypersonic flight and vehicles.

1 Introduction (6 hours)

- 1.1 History
- 1.2 Hypersonic flows properties
- 1.3 Hypersonic flow effects
- 1.4 Examples of hypersonic flight vehicles
- 1.5 Real gas effects and aerodynamic heating

2 Compressible Flows (4 hours)

- 2.1 Governing equations
- 2.2 Normal shock waves
- 2.3 Oblique shock waves
- 2.4 Standing shock wave over a sharp wedge
- 2.5 Detached shock wave over a blunt body
- 2.6 Internal and external compressible flows

3 Viscous Fluid Flow (5 hours)

- 3.1 Flow over a flat plate
- 3.2 Viscous and boundary layer properties
- 3.3 Thermal transport and temperature profile
- 3.4 Boundary layer separation

4 Inviscid Hypersonic Flow (16 hours)

- 4.1 Hypersonic shock wave relations
- 4.2 Hypersonic expansion wave relations
- 4.3 Local surface inclination methods
- 4.4 Approximate methods for hypersonic flows
- 4.5 Thin shock layer theory

- 4.6 Shock-shock interaction
- 4.7 Shock-expansion interaction
- 4.8 Introduction to method of characteristics

5 High-Speed Gas Dynamics (6 hours)

- 5.1 Dissociation and ionization in gases
- 5.2 Chemical reaction in gases
- 5.3 Shock-induced combustion
- 5.4 Detonation
- 5.5 Hypersonic propulsion systems
- 5.6 Shock-boundary layer interaction

6 Hypersonic Flight Vehicles (8 hours)

- 6.1 History
- 6.2 From ramjet to scramjet
- 6.3 The single-stage-to-orbit dream
- 6.4 Hypersonic programs of the last century
- 6.5 Millennium approach in hypersonics
- 6.6 Future of hypersonics

Tutorial (30 hours)

- 1. Formulate and solve the differential boundary layer equations for various flow configurations.
- 2. Predict and analyze conditions leading to flow separation over aerodynamic surfaces.
- 3. Evaluate shock wave-boundary layer interaction (SWBLI) phenomena and their impact on pressure distribution.
- 4. Construct and interpret shock polars to determine oblique shock behavior and flow deflection angles.
- 5. Calculate thermal boundary layer profiles, skin friction factors, and local heat transfer rates.

Practical (15 hours)

- 1. Computing pressure coefficient over arbitrary bodies
- 2. Developing a program to produce shock polar diagram
- 3. Development of conceptual modelling of full viscous flow path of a hypersonic vehicle

Final Exam

The questions will cover all the chapters in the syllabus. The evaluation scheme will be as indicated in the table below:

Chapters	Hours	Marks distribution*
1	6	8
2, 3	9	12
4	16	22
5	6	8
6	8	10
Total	45	60

* There may be minor deviation in marks distribution.

References

1. Bertin, J. J. (1994). Hypersonic aerothermodynamics (Latest Edition). American Institute of Aeronautics and Astronautics.
2. Anderson, J. D. (2019). Hypersonic and high-temperature gas dynamics. American Institute of Aeronautics and Astronautics.
3. Heppenheimer, T. A. (2018). Facing the heat barrier: A history of hypersonics. Dover Publications.
4. Hirschel, E. H. (2015). Basics of aerothermodynamics. Springer.

AVIATION LEGISLATION

ENAS 426

Lecture : 3
Tutorial : 2
Practical : 1

Year : IV
Part : I

Course Objectives:

The objective of this course is to provide detailed understanding of aviation regulation followed around the world. The course will also compare regulations between various states and regulatory bodies. The documentations followed during operations and maintenance programs will also be covered.

1 Regulatory Framework (15 hours)

- 1.1 International civil aviation organization (ICAO), International air transport association (IATA) and its roles
- 1.2 Conventions of ICAO and ICAO Annexes
- 1.3 Role of civil aviation authority of Nepal
- 1.4 Civil aviation act 1959 and subsequent amendments
- 1.5 Civil aviation authority act 1996 and subsequent amendments
- 1.6 Civil aviation rules 1996 and subsequent amendments
- 1.7 Civil aviation authority regulation 2002 and subsequent amendments
- 1.8 General introduction FAA and EASA
- 1.9 Certifying staff
- 1.10 Understanding of EASA Part 66
- 1.11 Detailed understanding of NCAR Part 66
- 1.12 Approved maintenance organization
- 1.13 Understanding of EASA Part M subpart F and Part 145
- 1.14 Detail understanding of NCAR Part 145 and NCAR Part M

2 Operation- Commercial Air Transportation (10 hours)

- 2.1 General understanding of EU-Operations
- 2.2 Air operator certificates and its requirement
- 2.3 Operator responsibilities- CAMO and AMO
- 2.4 Aircraft maintenance program (AMP)
- 2.5 Minimum equipment list and configuration deviation list (MEL/CDL)
- 2.6 Documents to be carried on board the aircraft
- 2.7 Aircraft placarding (Marking) requirement

3 Aircraft Certification (8 hours)

- 3.1 Design organization part 21 (EASA and NCAR)
- 3.2 Certification rules: Type certificates and supplemental type certificates
- 3.3 Certificate of airworthiness
- 3.4 Certificate of registration
- 3.5 Noise certificate
- 3.6 Weight schedule
- 3.7 Radio station license

4 Applicable National and International Requirement (8 hours)

- 4.1 Maintenance program
- 4.2 Maintenance checks and inspection
- 4.3 Airworthiness directives
- 4.4 Service bulletins and manufacturers service information
- 4.5 Modification and repair

5 Relevant Documentation (4 hours)

- 5.1 Maintenance documents and manuals
- 5.2 Master Minimum Equipment List (MMEL), Defect Dispatch List (DDL)
- 5.3 Continuing airworthiness- test flight
- 5.4 Category 2/3 operation, all weather operation
- 5.5 Extended-range Twin-engine Operational Performance Standards (ETOPS), maintenance and dispatch requirements

Tutorial (30 hours)

- 1. Review of design organizations
- 2. Comparison of FAA and EASA regulations
- 3. NCAR parts review
- 4. ETOPS and operational guidelines

Practical (15 hours)

- 1. Writing of report on various topics on aviation legislation
- 2. Creating short report and presentation on understanding of aviation legislation issues
- 3. Comparison of an Annex between ICAO and NCAR SARPS

Final Exam

The questions will cover all the chapters in the syllabus. The evaluation scheme will be as indicated in the table below:

Chapter	Hours	Marks distribution*
1	15	16
2	10	16
3	8	10
4	8	10
5	4	8
Total	45	60

* There may be minor deviation in marks distribution.

References

1. Bartsch, R. I. C. (2020). International Aviation Law: A Practical Guide. United Kingdom: Taylor & Francis Limited (Sales).
2. Civil Aviation Authority of Nepal. (2026). Nepal civil aviation regulations. Civil Aviation Authority of Nepal. Civil Aviation Authority of Nepal
3. European Union Aviation Safety Agency. (2026). Continuing airworthiness: Part-M, Part-145, Part-66, and related requirements. European Union Aviation Safety Agency. EASA regulations-Continuing Airworthiness
4. Federal Aviation Administration. (2026). Airworthiness directives (ADs). U.S. Department of Transportation, Federal Aviation Administration. FAA Airworthiness Directives
5. Rollo, V. A. F. (1979). Aviation Law: An Introduction. United States: Maryland Historical Press.

GUIDANCE, NAVIGATION AND CONTROL FOR UAV

ENAS 427

Lecture : 3
Tutorial : 2
Practical : 1

Year : IV
Part : I

Course Objectives:

The objective of this course is to provide students with knowledge of Unmanned Aerial Vehicle (UAV) dynamics, flight stabilization, localization, state estimation, path planning, autonomous control and cooperative UAV systems. Students will learn modern robotics and flight control approaches used in autonomous UAV operations.

1 UAV Dynamics and Modeling (7 hours)

- 1.1 UAV guidance, navigation and control
- 1.2 Coordinate systems and reference frames
- 1.3 Coordinate transformations
- 1.4 Translational dynamics of UAVs
- 1.5 Rotational dynamics of UAVs
- 1.6 Six-degree-of-freedom UAV model
- 1.7 State-space modeling of UAV systems

2 Modelling and Control (8 hours)

- 2.1 Flight stability
- 2.2 Mathematical modelling of a UAV
- 2.3 PID control
- 2.4 Cascaded control architecture
- 2.5 Attitude and altitude control
- 2.6 Adaptive control systems

3 Localization and Navigation (6 hours)

- 3.1 UAV navigation systems
- 3.2 GPS/GNSS navigation
- 3.3 Dead reckoning
- 3.4 Inertial navigation system
- 3.5 Position, velocity and attitude estimation
- 3.6 Navigation in GPS-denied environments
- 3.7 UAV localization challenges

4 Estimation and Sensor Fusion (8 hours)

- 4.1 State estimation

- 4.2 Sensor noise and uncertainty
- 4.3 Kalman filtering
- 4.4 Extended Kalman filter
- 4.5 Complementary filtering
- 4.6 IMU, GPS, magnetometer and barometer fusion
- 4.7 Sensor fusion for autonomous UAVs

5 Motion Planning (10 hours)

- 5.1 UAV motion planning
- 5.2 Path planning and trajectory planning
- 5.3 A* algorithm
- 5.4 Trajectory generation
- 5.5 Obstacle avoidance
- 5.6 Potential field methods
- 5.7 Mission planning for autonomous UAVs

6 Swarm and Cooperative Control (6 hours)

- 6.1 Multi-UAV systems
- 6.2 Multi-agent coordination
- 6.3 Formation flight
- 6.4 Leader-follower control
- 6.5 Consensus algorithms
- 6.6 Cooperative mission planning
- 6.7 Applications of swarm UAV systems

Tutorial (30 hours)

- 1. Coordinate transformation problems for UAV reference frames
- 2. State-space modeling exercises for multirotor UAVs
- 3. PID controller design and tuning calculations
- 4. INS error analysis and localization case studies
- 5. Kalman filter prediction and correction problem-solving
- 6. Sensor fusion exercises using IMU, GPS, barometer and magnetometer data
- 7. A* path planning numerical examples
- 8. Obstacle avoidance using potential field method

Practical (15 hours)

- 1. PID tuning and UAV controller design
- 2. MATLAB/Python-based UAV dynamics simulation
- 3. EKF implementation for UAV state estimation
- 4. Path planning simulation using A* algorithm
- 5. Obstacle avoidance simulation using potential field method
- 6. PX4 controller analysis and flight mode study

Final Exam

The questions will cover all the chapters in the syllabus. The evaluation scheme will be as indicated in the table below:

Chapter	Hours	Marks distribution*
1	7	9
2	8	11
3	6	9
4	8	11
5	10	12
6	6	8
Total	45	60

* There may be minor deviation in marks distribution.

References

1. Beard, R. W., McLain, T. W. (2012). Small unmanned aircraft: Theory and practice. Princeton University Press.
2. Stevens, B. L., Lewis, F. L., Johnson, E. N. (2015). Aircraft control and simulation. Wiley.
3. Titterton, D. H., Weston, J. L. (2004). Strapdown inertial navigation technology. Institution of Engineering and Technology (IET).
4. Grewal, M. S., Andrews, A. P., Bartone, C. G. (2020). Global navigation satellite systems, inertial navigation, and integration. Wiley.
5. Siciliano, B., Sciavicco, L., Villani, L., Oriolo, G. (2009). Robotics: Modelling, planning and control. Springer.
6. PX4 Development Team. (2025). PX4 autopilot user guide. PX4 Development Team.
7. ArduPilot Development Team. (2025). ArduPilot documentation. ArduPilot Development Team.