Course Type	Course Code	Name of Course	L	T	P	Course Credit
DE	NMED545	Introduction to Aerial Robotics	3	0	0	3

Course Objective
• Expose students to principles, modelling, control, and autonomous operation of aerial robotic systems. • Develop understanding of rigid body kinematics, dynamics, and flight mechanics. • Introduce trajectory planning, state estimation, sensor fusion, and autonomous navigation. • Familiarise students with design, simulation, control, and applications of aerial robots.
Learning Outcomes
Upon successful completion of this course, students will: • Understand fundamentals, classifications and applications of aerial robots. • Analyse rigid body kinematics and mathematical models. • Model and design quadrotor dynamics and flight control. • Apply trajectory planning, localisation, and sensor fusion. • Evaluate advanced aerial robotic technologies and applications.

Unit No.	Topics to be Covered	Lecture Hours	Learning Outcome
1	Introduction to Aerial Robotics: Evolution of UAVs, classifications, quadrotors, applications, autonomous flight, challenges, and key components of aerial robotic systems.	3	Understand architecture, challenges and applications of aerial robots.
2	Rigid Body Motion and Geometry: Coordinate frames, homogeneous transformations, rotation matrices, Euler angles, quaternions, angular velocity.	4	Understand representing any rigid body motion and kinematic transformations.
3	Flight/Quadrotor Mechanics and Dynamics: Newton–Euler formulation; quadrotor configuration; forces and moments; aerodynamics of a rotating propeller: thrust and torque; concepts of mutual aerodynamic interference of multiple neighbouring rotors, inertial properties; equations of motion; mathematical modelling; state-space representation.	6	Analyse the quadrotor dynamic equation of motion. Aerodynamics of propeller, Mathematical Modelling and State Space Representation.
4	Design of Aerial Robots: Design considerations; agility and manoeuvrability; actuator and propeller selection; motor sizing; payload estimation; battery selection; vehicle size and configuration.	3	Understand engineering design and trade-offs in aerial robot development.
5	Flight Control of Quadrotors: Linear control; attitude stabilisation; altitude control; position control; trajectory tracking; cascaded controllers; nonlinear control concepts; controller implementation.	6	Design and analyse attitude, altitude and position controllers. Learn to implement quadrotor flight controller.
6	Trajectory Generation and Motion Planning: Motion primitives; minimum-jerk trajectories; trajectory generation; trajectory optimisation; waypoint navigation; collision-free motion planning; autonomous flight planning.	4	Generate trajectories and plan safe, efficient flight paths.

7	State Estimation and Sensor Fusion: IMU; GPS; vision sensors; position and orientation estimation; Kalman filtering concepts; localisation; sensor fusion; perception for aerial robots.	6	Apply localisation, state estimation and sensor fusion for autonomous flight.
8	Advanced Topics in Aerial Robotics: Multi-robot coordination; swarm aerial robotics; cooperative aerial systems; autonomous navigation; emerging research challenges; future trends.	6	Understand swarm robotics, cooperative systems and emerging trends.
9	Simulation and Applications: Modelling and simulation of aerial robots; simulation-based control evaluation; aerial inspection; mapping; surveillance; disaster management; logistics; precision agriculture.	4	Simulate and evaluate aerial robotic systems for practical applications.
	Total	**42**	

Textbooks:

1. Introduction to Autonomous Mobile Robots – Roland Siegwart, Illah Reza Nourbakhsh, Davide Scaramuzza, MIT Press, Second Edition, 2011.
2. Small Unmanned Aircraft: Theory and Practice – Randal W. Beard, Timothy W. McLain, Princeton University Press, 2012.

Reference Books:

1. Planning Algorithms – Steven M. LaValle, Cambridge University Press, 2006
2. Probabilistic Robotics – Sebastian Thrun, Wolfram Burgard and Dieter Fox, MIT Press, 2005
3. Modern Robotics – Kevin M. Lynch and Frank C. Park, Cambridge University Press, 2017
4. Feedback Systems – Karl J. Åström and Richard M. Murray, Princeton University Press, 2008
5. Introduction to Robotics: Mechanics and Control, John J. Craig, Pearson Education International, Third Edition, 2005.
6. Robot Modelling and Control – Mark W. Spong, Seth Hutchinson, M. Vidyasagar, Wiley, Second Edition, 2020.
7. Quadrotor Dynamics and Control – Randal W. Beard (Course Notes)