Program Structure and Syllabus of Minors/Honors in Space Technology

ELECTRONICS & COMMUNICATION ENGINEERING (ECE)

R24Regulations

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Minor/Honors in Space Technology

Curriculum Structure

S.No	Course Code	Course Name	Credit Scheme			
			Lecture	Tutorial	Practical	Total
1		Introduction to Space Technology	3	-	-	3
2		Launch Vehicle Systems and Technologies	-	-	4	2
3		Spaceflight Mechanics and Attitude Dynamics	3	-	4	5
4		Spacecraft Systems Engineering	3	-	4	5
5		Project	-	-	6	3
	Total Credits		**9**	**0**	**18**	**18**

Introduction to Space Technology

Minor Degree in Space Technology					Department of Electronics & Communication Engineering			
Code	**Category**	**Hours / Week**			**Credits**	**Marks**		
	Core	L	T	P	C	CIE	SEE	Total
		3	0	0	3	-	100	100

Prerequisites: Engineering Physics, Engineering Mathematics

Course Objectives: Familiarize students with

1. Concepts of launch vehicle design and missiles
2. Various parameters required for mission trajectory design and launch
3. Space data products and services
4. Space technology and laws

Unit – I: Basics of Launch Vehicle Design and Missiles

GNC and Satellite Systems Engineering design. Fundamentals of structure and mechanisms. Introduction to launch facilities, launch vehicle assembly, integration and launch readiness. Communication with the ground stations and ground tracking in collaboration with foreign space centers

Unit – II: Fundamentals of mission trajectory design

Coordinate reference frames, space flight mechanics, satellite orbits, Kepler's laws; lunar and interplanetary missions. Attitude dynamics, Attitude parameterization: direction cosine matrix, Euler axis and angles, quaternions, Euler angles; attitude rates; attitude determination; Euler equations of motion and attitude dynamics

Unit – III: Basics of Space data products and services including AI and ML

Definition and Overview of Remote Sensing and Remote Sensing Systems: Electromagnetic Radiation, Laws of Radiation, EM Spectrum, Sources of EMR, Interaction between EM Radiation and matter, Reflection, Absorption and Transmission, Interactions between EM Radiation and Atmosphere, Atmospheric windows. Platforms: Types of platforms (Ground, Airborne and Space borne); Satellites for earth observation; Geostationary and UAV platforms.

Unit – IV: Space Technology

Fundamentals of Digital Image Processing, Fundamentals of Photogrammetry, Cartography, space materials processing; Global Navigation Satellite System (GNSS)

Unit- V: Space Law and Policy

Introduction to the need and overview of Space Laws and its interface with International Conventions and Treaties, Introduction and Basic Principles of International Laws, Indian Space Bill and Space policy 2022, Space-enabled Communication and Services Regulation, Space tourism

Text Books:

1. Wie, B., Space Vehicle Dynamics and Control, 2nd ed., AIAA Education Series, 2008
2. Zarchan, P., Tactical and Strategic Missile Guidance, 6th ed., Progress in Astronautics and Aeronautics, 2007

Reference Books:

1. Joseph, G., Fundamentals of Remote Sensing, Universities Press, 2003
2. Fleeman, E. L., Missile Design and System Engineering, AIAA Education Series, 2012
3. Noton, M., Spacecraft Navigation and Guidance, Springer 1998
4. Farrell, J. A., Aided Navigation: GPS with High Rate Sensor, McGraw-Hill 2008

Course Outcomes:

Students will be able to:

1. Discuss concepts of launch vehicle design and missiles
2. Determine various parameters required for mission trajectory design and launch.
3. Use Space data products and services
4. Explain Space technology concepts and laws

Launch Vehicle Systems and Technologies Lab

Minor Degree in Space Technology					Department of Electronics & Communication Engineering			
Code	**Category**	**Hours / Week**			**Credits**	**Marks**		
	Core	L	T	P	C	CIE	SEE	Total
		0	0	4	2	-	100	100

Prerequisites: Engineering Physics, Engineering Mathematics

Course Objectives: Familiarize students with

1. Concepts of launch vehicle design and missiles
2. Launch Vehicle Dynamics
3. Fundamentals of GNC loop, design problem and algorithms
4. Mechanism of Descent and landing

Unit–I: Launch Vehicles and Missiles and their subsystems

Launch Vehicles and Missiles and their subsystems, Fundamentals and Types of Propulsion system: Solid / Liquid / Cryogenic / Semi-Cryogenic /Mono- propellent, Bi-propellent and Electric propulsion systems (including green propulsion) Fundamentals of Structures and Mechanisms: Structural Dynamics /Vibration modes for Dynamics modeling

Unit –II: Launch Vehicle Dynamics

Gravity model, Point mass dynamics, Aerodynamics: Multi-strap-on Vehicles, its aerosurfaces, Fundamentals of Trajectories (Mission Design): Equations of Motion: short period / long period Model development, Slosh Dynamics analysis, Basic principles of inertial measurement units: Gyros, Fiber optic/ Laser Gyros and others, accelerometers, Actuators: Electrohydraulic, Electromechanical, Reaction Control Systems

Unit –III: Fundamentals of GNC loop, design problem and algorithms

Basics of Guidance: Open Loop / Closed Loop: Implicit / Explicit Guidance schemes, Basics of Navigation: Nav algorithm, compensation schemes, multiple sensor fusion, Basics of Control (Autopilot): Linear / nonlinear design Techniques

Unit –IV: Validation Testbeds/ Simulation setups

On-board computer in the loop simulations (OILS), Hardware in the loop Simulations (HLS), Actuators in Loop Simulations (ALS), Flight Software in Loop Simulations (SILS), reliability analysis, Satellite interface and satellite deployment with separation dynamics

Unit- V: Descent and landing

Descent and landing of jettisoned stages, communication with ground stations, ground tracking in collaboration with foreign space center

Text Books

1. Edberg, D., and Costa, W., Design of Rockets and Space Launch Vehicles, AIAA Education Series, 2020
2. Kadam, N. V., Practical Design of Flight Control Systems for Launch Vehicles and Missiles, Allied Publishers, 2009

Reference Books

1. Wiesel, W. E., Spacecraft Dynamics, 2nd ed, McGraw-Hill 1997
2. Noton, M., Spacecraft Navigation and Guidance, Springer 1998

Course Outcomes: Students will be able to:

1. Discuss concepts of launch vehicle design and missiles
2. Explain Launch Vehicle Dynamics
3. Apply Fundamentals of GNC loop, design problem and algorithms
4. Describe Mechanism of Descent and landing

Spaceflight Mechanics and Attitude Dynamics

Minor Degree in Space Technology					Department of Electronics & Communication Engineering			
Code	**Category**	**Hours / Week**			**Credits**	**Marks**		
	Core	L	T	P	C	CIE	SEE	Total
		3	0	4	5	-	100	100

Prerequisites: Engineering Physics, Engineering Mathematics

Course Objectives: Familiarize students with

1. Concepts of Spaceflight Mechanics
2. Spacecraft Attitude Dynamics and control system
3. Remote Sensing and Propulsion Systems
4. Flight Mechanics and Missile Guidance

Unit – I: Spaceflight Mechanics

ECI frame, Two-body Orbital dynamics, Integrals of motion, Classical Orbital parameters, Satellite Orbit perturbations, sun-synchronous satellites, geo- synchronous, orbital manoeuvres, orbit determination, orbit corrections and maintenance, relative motion in orbits, proximity operations

Unit – II: Spacecraft Attitude Dynamics

Attitude parameterization: direction cosine matrix, Euler axis and angles, Quaternions, attitude rates, Euler equations of rigid body attitude dynamics. Liquid propellant slosh effects. Aattitude stabilization, spin stabilization of a rigid spacecraft and an energy-dissipating Spacecraft, active nutation control, momentum bias satellites, passive and active nutation damping, control with Thrusters

Unit – III: Spacecraft Attitude Control

Attitude control with three-axis reaction wheels, thrusters and magnets; Three- Axis Stabilization, Disturbing torques, effect of structural flexibility, antenna beam pointing accuracy. Various types of attitude sensors, attitude determination

Unit – IV: Remote Sensing and Propulsion Systems

Earth coverage by low-earth orbit and high-earth orbit remote sensing satellites; infrared and radar remote sensing from space, Propulsion Systems, Liquid Propellant Thrusters, Electric Propulsion

Unit- V: Flight Mechanics and Missile Guidance

Re-entry Flight Mechanics, guided re-entry, feedback guidance, Lunar and interplanetary flights: Chandrayan and Mars missions.

Missile guidance: Lambert, midcourse and endgame guidance; Tactical and strategic interceptors, zero-effort-miss guidance; Cruise missiles, Fundamentals of Space-based Navigation (GNSS)

Text Books

1. De Ruiter, A. H. J., Damaren, C. J., and Forbes, J. R., Spacecraft Dynamics and Control: An Introduction, Wiley 2013
2. Montenbruck, O., and Gill, E., Satellite Orbits: Models, Methods, Applications, Springer 2000
3. Sidi, M. J., Spacecraft Dynamics and Control, Cambridge University Press 1997
4. Wie, B., Space Vehicle Dynamics and Control, 2nd ed., AIAA Education Series, 2008

Reference Books

1. Chobotov, V. A., (Ed.), Orbital Mechanics, 3rd ed, AIAA Education Series 2002
2. Wiesel, W. E., Spacecraft Dynamics, 2nd ed, McGraw-Hill 1997
3. Noton, M., Spacecraft Navigation and Guidance, Springer 1998
4. Farrell, J. A., Aided Navigation: GPS with High Rate Sensor, McGraw-Hill 2008
5. Joseph, G., Fundamentals of Remote Sensing, Universities Press, 2003
6. Fleeman, E. L., Missile Design and System Engineering, AIAA Education Series, 2012

7. Zarchan, P., Tactical and Strategic Missile Guidance, 6th ed., Progress in Astronautics and Aeronautics, 2007

Course Outcomes:

Students will be able to:

1. Discuss concepts of Spaceflight Mechanics
2. Determine various parameters required for Spacecraft Attitude Dynamics and control system.
3. Explain remote sensing systems and various Propulsion Systems.
4. Describe Flight Mechanics and Missile Guidance

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Spacecraft Systems Engineering

Minor Degree in Space Technology					Department of Electronics & Communication Engineering			
Code	**Category**	**Hours / Week**			**Credits**	**Marks**		
	Core	L	T	P	C	CIE	SEE	Total
		3	0	4	5	-	100	100

Prerequisites: Engineering Physics, Engineering Mathematics

Course Objectives: Familiarize students with

1. Fundamentals of Spacecraft Configurations and Satellite subsystems
2. Spacecraft Structures and Thermal Control System
3. Satellite Communication principles
4. Basics of remote sensing satellites and ground segments

Unit – I: Spacecraft Configurations and Satellite subsystems

Mission analysis and design, Space Environment and space weather, Disturbances acting on a satellite, Fundamentals of on-board computer and control electronics, on-board software development for attitude and orbit control, propulsion, electrical power, solar arrays, batteries, power control electronics, telemetry and telecommand, mechanism, radiation tolerance, electromagnetic compatibility

Unit – II: Spacecraft Structures and Thermal Control System

Introduction, Spacecraft Structural Configuration, Launch Loads, Stress-Strain Analysis, Matrix Methods of Structural Analysis, Finite Element Analysis, Instability of Structures, Dynamic Analysis, Multi-Degree-of-Freedom System, Random Excitation, Mode Synthesis, Materials, Structural Design Verification Tests, Introduction, Heat Transfer, Thermal Analysis, Thermal Control Techniques, Spacecraft Thermal Design, Thermal Testing

Unit – III: Satellite Communication

Basic Units and Definitions in Communications Engineering, Frequency Allocations and Some Aspects of the Radio Regulations, Electromagnetic Waves, Frequency, and Polarization Selection for Satellite Communications, Link Consideration, Communications Subsystem of a Communications Satellite, Some Common Modulation and Access Techniques for Satellite Communications, Satellite Capacity and the Sizing of Satellites, Advanced communication systems in LEO, MEO and GEO, Small satellites: engineering and applications

Unit – IV: Remote Sensing Satellites

Payloads of communication satellites, remote sensing satellites, navigation satellites, science mission satellites and missile detection. Optical, Quantum Satellite communication

Unit- V: Ground Segment

Ground segment: assembly, integration, and verification, Quality control and product assurance

Text Books

1. Larson, W. J., and Wertz, J. R., (Eds.), Space Mission Analysis and Design, Springer 2006
2. Fortescue, P., Swinerd, G., and Stark, J., (Eds.), Spacecraft Systems Engineering, 4th ed., Wiley 2011
3. Griffin, M. D., and French, J. R., Space Vehicle Design, 2nd ed, AIAA Education Series 2004

Reference Books

1. Maini, A. K., and Agrawal, V., Satellite Technology: Principles and Applications, Wiley 2007
2. Sandau, R., Roser, H.-P, and Valenzuela, (Eds.), Small Satellites for Earth Observation, Springer 2008

Course Outcomes: Students will be able to

1. Discuss fundamentals of Spacecraft Configurations and Satellite subsystems
2. Elaborate Spacecraft Structures and Thermal Control System

3. Apply Satellite Communication principles
4. Explain remote sensing satellites and ground segments.

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Project

Minor Degree in Space Technology					Department of Electronics & Communication Engineering			
Code	**Category**	**Hours / Week**			**Credits**	**Marks**		
	Core	L	T	P	C	CIE	SEE	Total
		0	0	6	3	-	100	100