Syllabus: Introduction to different navigation systems, navigation coordinate frames, geometry of Earth, attitude and its parameterizations, standard navigation filters (least squares estimation and Kalman filter), overview of Global Navigation Satellite System (GNSS) architecture, signal structure of the Global Positioning System (GPS) and Indian Regional Navigation Satellite System (IRNSS), GNSS receiver operating principles, pseudorange, pseudorange rate and carrier phase measurements, error models, user position, velocity and time (PVT) estimation, dilution of precision, carrier phase differential GNSS, overview of inertial navigation system (INS), INS error characteristics, INS mechanization, GNSS-INS integration architectures.

Lecture-wise breakup:

Lectures		Contents
Week 1	Lecture 1	Subject overview, navigation techniques and navigation systems
	Lecture 2	Navigation systems continued, definition of different coordinate systems
	Lecture 3	Geoid, Ellipsoid model, curvilinear position (part 1)
	Tutorial	Problems on topics covered
Week 2	Lecture 1	Ellipsoid model, curvilinear position (part 2)
	Lecture 2	Definition of vehicle attitude and various ways of representing attitude (part 1)
	Lecture 3	Definition of vehicle attitude and various ways of representing attitude (part 2)
	Tutorial	Problems on topics covered
Week 3	Lecture 1	Basics of probability theory
	Lecture 2	Basics of random variables (part 1)
	Lecture 3	Basics of random variables (part 2)
	Tutorial	Problems on topics covered
Week 4	Lecture 1	Random variables (part 3), random vectors and processes
	Lecture 2	Weighted least squares, minimum mean square, and linear minimum mean square estimators
	Lecture 3	Kalman filter and Extended Kalman filter algorithms
	Tutorial	Kalman filter implementation on a practical problem
Week 5	Lecture 1	Overview of GNSS architecture, GNSS applications, GNSS spacecraft orbits
	Lecture 2	Global Positioning System (GPS) signal structure (part 1)
	Lecture 3	GPS signal structure (part 2)

	Tutorial	Indian Regional Navigation Satellite System (IRNSS) signal structure
Week 6	Lecture 1	Class test
	Lecture 2	GPS signal structure (part 3)
	Lecture 3	Signal propagation medium (Ionosphere and Troposphere)
	Tutorial	Problems on topics covered
Week 7	Lecture 1	Overview of GNSS receiver operating principles, receiver antenna
	Lecture 2	GNSS receiver operating principles – receiver front end (part 1)
	Lecture 3	GNSS receiver operating principles – receiver front end (part 2)
	Tutorial	Review of receiver front end, problems on topics covered
Week 8	Lecture 1	GNSS receiver operating principles – Receiver baseband signal processor, signal correlation
	Lecture 2	GNSS receiver operating principles – signal acquisition
	Lecture 3	GNSS receiver operating principles – signal tracking (part 1)
	Tutorial	Transfer function block diagram of signal tracking loops
Week 9	Lecture 1	GNSS receiver operating principles – signal tracking (part 2)
	Lecture 2	Derivation of pseudorange, pseudorange rate and carrier phase measurements
	Lecture 3	GNSS receiver navigation filter – error models, user position, velocity and time estimation (part 1)
	Tutorial	Review of weeks 8 and 9
Week 10	Lecture 1	GNSS receiver navigation filter (part 2)
	Lecture 2	Dilution of precision
	Lecture 3	Class test
	Tutorial	Carrier phase differential GNSS (part 1)
Week 11	Lecture 1	Overview of INS and their applications, Inertial navigation sensors – Accelerometers and gyroscopes
	Lecture 2	Inertial navigation sensor error characteristics, INS vertical channel instability
	Lecture 3	INS error propagation (flat vs. curved Earth) (part 1)
	Tutorial	Carrier phase differential GNSS (part 2)
Week 12	Lecture 1	INS error propagation (flat vs. curved Earth) (part 2)
	Lecture 2	INS mechanization equations (part 1)
	Lecture 3	INS mechanization equations (part 2)
	Tutorial	Carrier phase differential GNSS (part 3)

Week 13	Lecture 1	Loose GNSS-INS integration architecture
	Lecture 2	Tight GNSS-INS integration architecture
	Lecture 3	GNSS-INS integration for a practical problem
	Tutorial	GNSS-INS integration for a practical problem