University of Isfahan

Geodesy Engineering Graduate Program

Curriculum

Department of Geomatics Engineering

Faculty of Civil and Transportation Engineering

University of Isfahan

January 8, 2024

1- Introduction

Geodesy, a field of surveying and mapping related to determining the Earth's shape and gravity, has a long-standing history as an engineering discipline. However, it was not introduced in Iran until 1988, when distinguished foreign professors were brought to the KNT University of Technology to establish the field there. This recruitment of international experts in geodesy continued until 1996. As more Iranian students graduated with expertise in geodesy, specialized Geodesy departments were set up at various universities across the country. Presently, several prominent Iranian universities - including Isfahan University, KNT University, and Tehran University - all offer graduate programs in geodesy up to the doctoral level.

2- Objectives and importance of engineering geodesy

Geodesy focuses on measuring the planet's shape, size, and gravity field. This field has applications across many scientific disciplines, including aerospace, military sciences, geology, remote sensing, meteorology, and other sciences and techniques. With the recent advancements in space sciences, the applications of geodesy in this domain have become increasingly essential.

Geodesy requires a strong foundation in mathematics, statistics, probability, and advanced physics, making certain subfields of geodesy quite close to the basic sciences. This has been reflected in the design and revision of geodesy curricula. On the other hand, many branches of geodesy, such as satellite geodesy and Global Navigation Satellite Systems (GNSS), are more closely aligned with engineering sciences. So, geodesy encompasses both scientific principles as well as specialized engineering applications, especially in areas like satellite technology and precise positioning, highlighting the multidisciplinary nature of this field.

A key focus in space sciences is the precise determination of satellite orbits. The International GNSS Service, which provides centimeter-level accurate orbit data, and the International Earth Rotation and Reference Systems Service (IERS) which provides orbit reference frames, are affiliated with international geodesy organizations. Studying satellite orbits is one of the key methods used for accurately modeling the Earth's gravity field. Courses in geodesy often cover topics related to the Earth's gravity field and both global and local geopotential models.

Another important area of study and research in geodesy and geodynamics is global and regional plate tectonic movements. This field has applications in earthquake studies and geophysics. The networks of permanent GNSS (Global Navigation Satellite System) stations have been very helpful in this domain, as the time series data from these stations play a crucial role in geodynamics research.

Geodesy places particular emphasis on satellite geodesy and Global Navigation Satellite Systems (GNSS). Beyond general GNSS applications, these technologies enable high-precision measurements, with geodesy focused on achieving millimeter-level accuracy and continuing to improve such precision.

Key areas of focus in geodesy include techniques for resolving phase ambiguity, as well as developing accurate models for estimating biases and atmospheric parameters. The use of GNSS data has led to significant advancements in meteorological studies, particularly for ionosphere and troposphere research. For example, the Geomatics Engineering Department at Isfahan University in Iran has conducted notable research and published articles on ionospheric and tropospheric studies using GNSS data.

Additionally, discussions on estimation and approximation theory, as well as time series analysis, are of particular importance for geodetic applications. Nonlinear estimators and integer estimators are covered in relevant courses within geodesy curricula.

The core geodesy curriculum places significant emphasis on recent advancements in the field, particularly in areas such as satellite and space geodesy, inertial systems, as well as new theories and techniques for phase ambiguity resolution and orbit determination. To keep pace with these developments, the course content has undergone substantial revisions, and new courses have been designed to address emerging topics.

One of the most fundamental issues in geodesy and related sciences like geophysics and geodynamics is the discussion of reference systems and frames. Concepts such as the International Terrestrial Reference Frame (ITRF) and the International Celestial Reference Frame (ICRF) are essential knowledge for geodesy experts.

3- Skills and Expertise of Geodesy Graduates

In general, a graduate in the field of geodesy should possess a range of abilities and skills. However, the specific depth of knowledge in each of these areas would depend on the individual graduate's research focus and thesis work.

Proficiency in estimation theory and advanced adjustment techniques, and their applications in geodesy.

Expertise in satellite geodesy topics, including orbit determination, atmospheric modeling, timing, positioning, and other satellite-based methods.

Knowledge of space geodesy, Very Long Baseline Interferometry, gravity field missions, and InSAR techniques.

Familiarity with the data sources from international geodetic services.

Ability to process GNSS data and develop software for research and scientific applications.

Capability to extract meteorological information, such as ionosphere and troposphere data, from GNSS observations.

Understanding of geopotential models and principles of geoid determination.

Competence in utilizing data from gravity field missions.

Expertise in reference systems and frames, and the ability to perform conversions between them.

Proficiency in GNSS Precise Point Positioning Technique.

Skill in time series analysis of geodetic data.

4- Educational and research programs

This program provides a curriculum of courses (lectures, seminars, and a thesis) designed to enhance students' research capabilities and equip them with the latest advancements in geodesy. The program offers core courses and electives for both master's and doctoral students (details in Table 3). With the consent of their supervisor and departmental approval, students can supplement their studies with 3-unit electives from other related fields, ensuring they meet the total credit requirements for their degree.

4-1 Master's degree

To earn a Master's degree in geodesy, students must complete 32 units. This includes:

6 core courses (listed in Table 3) totaling 14 units.

4 elective courses (chosen with supervisor guidance and departmental approval from Table 4) totaling 12 units.

A Master's thesis worth 6 units.

4-2 Doctoral degree

1. Educational & Research Based: Students take 6 elective courses (18 units) from Table 4, plus an 18-unit doctoral thesis course.
2. Research Based: Students choose 1-3 elective courses (3-6 units) from Table 3 with advisor approval and a doctoral dissertation worth 30-33 units.

4-3 Prerequisite Courses

1. **Master's Level:** Students without a surveying engineering background need to bolster their foundation by taking **prerequisite courses**. These include at least two from physical geodesy, satellite geodesy, adjustment, and geodetic surveying, as recommended by the

department. Passing these mandatory courses is essential, but they don't count toward graduation credits.

2. **Doctorate Level:** Doctoral students may require additional coursework beyond the core curriculum (Table No. 3). These **supplemental courses** will be chosen in consultation with the supervisor and approved by the department. Similar to the Master's level, these additional courses are mandatory but don't contribute to the total program credits.

5- Educational and Research Programs

The required units for each degree and educational method (educational or research) in geodesy comply with the approvals of the Ministry of Science, Research and Technology and the University of Isfahan. Details are provided in Table 1.

Table 1: Course Requirements for Geodesy Programs (Degrees & Methods)

PhD Research-Based	PhD Educational and Research-Based	Master	courses
Selection from the table of core courses	Selection from the table of core courses	Up to 12 units of bachelor courses	**Prerequisite**
-	-	14	Core
2 to 3	18	12	Elective courses
30 to 33	18	6	Thesis
36	36	32	Sum of units

6-Scope and method of work in thesis/dissertation

Geodesy theses and dissertations tackle diverse topics aligned with graduate skillsets (Section 3). Students actively explore research questions, leveraging their chosen area's latest advancements. The research process involves:

1. Literature Review: Building a strong theoretical foundation through in-depth review.
2. Data Acquisition & Analysis: Students gather, prepare, and analyze data (including field data) to extract valuable insights.
3. Method Development (Optional): Doctoral dissertations may push theoretical boundaries or develop regional algorithms (for Ph.D. only).
4. Result Validation: Rigorous quality control ensures the accuracy and reliability of findings.

Table 2: Prerequisite Courses for the PhD. in Engineering Geodesy

		Units		Hours	
		Theory	Practical	Theory	Practical
1	**Advanced Estimation Theory**	3	---	48	---
2	**Geometric geodesy**	3	---	48	---
3	**Advanced satellite precise positioning**	3	---	48	---

Table 3: Core Courses for the MSc. in Engineering Geodesy

	Course	Units		Hours	
		Theory	Practical	Theory	Practical

1	**Advanced geodynamics**	3	---	48	---
2	**Advanced satellite geodesy**	3	---	48	---
3	**Advanced approximation theory**	3	---	48	---
4	**Time series analysis**	3	---	48	---
5	**Research Method in GeoScience**	1	---	16	---
6	**Seminar**	1	---	16	---
Sum	14				

Table 4: Elective Courses for the PhD. And MSc. in Engineering Geodesy

	Course	Units		Hours	
		Theory	Practical	Theory	Practical
1	**Advanced Geodynamic**	3	---	48	---
2	**Advanced Satellite Geodesy**	3	---	48	---
3	**Advanced Approximation Theory**	3	---	48	---
4	**Time Series Analysis**	3	---	48	---
5	**Advanced Physical Geodesy**	3	---	48	---
6	**Precise Techniques in Space Geodesy**	3	---	48	---
7	**Map Projections in Geodesy**	3	---	48	---
8	**Atmosphere in Space Geodesy**	3	---	48	---
9	**Geophysics**	3	---	48	---
10	**Inertial Navigation Systems and GNSS/INS Integration**	3	---	48	---
11	**Theory and applications of Satellite Orbit Determination**	3	---	48	---
12	**Precise Navigation**	3	---	48	---
13	**Special Algorithms in GNSS**	3	---	48	---
14	**Advanced Statistics**	3	---	48	---
15	**Special Studies in Geodesy**	3	---	48	---
16	**Advanced Hydrography**	3	---	48	---
17	**Stochastic Processes**	3	---	48	---
18	**Advanced Optimization Algorithms**	3	---	48	---

19	**Tensorial Deformation Analysis**	3	---	48	---
20	**Satellite Gravimetry**	3	---	48	---
21	**Continuum Mechanics**	3	---	48	---
22	**Geodynamic Modeling**	3	---	48	---
23	**Theory of Invers Problem and Regularization**	3	---	48	---
24	**Functional Analysis**	3	---	48	---
25	**Advanced Estimation Methods**	3	---	48	---
26	**RADAR Altimetry & Interferometry**	3	---	48	---
27	**Digital Terrain Modeling**	3	---	48	---
28	**Orbital Mechanics**	3	---	48	---
29	**Atmospheric Remote Sensing**	3	---	48	---
30	**Intelligent Computation**	3	---	48	---

List of Core and Elective Courses

Core Courses

Advanced Satellite Geodesy

BASIC INFORMATION

Place in curriculum, title, and semester: core, Advanced satellite geodesy, S2
Number of credits: 3

COURSE PREREQUISITES

COURSE CO-REQUISITES

TEACHERS

The person in charge: Dr. Jamal Asgari
Office location: Department of Geomatics Engineering, Faculty of Civil Engineering & Transportation, University of Isfahan, Isfahan, 81746-73441, Iran
Phone number: +98-37935290
Homepage: https://engold.ui.ac.ir/~asgari/
Email address: asgari@eng.ui.ac.ir
Other instructors: --

WEEKLY HOURS

Theory	Problem Solving	Laboratory	Guided learning
3 h	--	---	---

COURSE OBJECTIVES

THIS COURSE DELVES INTO THE FUNDAMENTALS OF SATELLITE GEODESY, COVERING TOPICS SUCH AS ORBITS AND ATMOSPHERIC INFLUENCES. UNDERSTANDING THESE CORE PRINCIPLES IS ESSENTIAL GIVEN THE SWIFT ADVANCEMENTS IN THE FIELD.

REQUIRED STUDENT RESOURCES

References:

1. G. Seeber, "Satellite Geodesy: Foundations, Methods, and Applications", Walter de Gruyter, Berlin New York, 2nd Edition, 2003.
2. B. Hofmann-Wellenhof, H. Lichtenegger, and E. Wasle, "GNSS – Global Navigation Satellite Systems, GPS, GLONASS, Galileo, and More", Springer-Verlag, Wien NewYork 2008.
3. A. Leick, L. Rapoport and D. Tatarnikov "GPS satellite surveying ", Wiley, Hoboken, 4th Edition 2015.
4. H.D. Curtis, "Orbital Mechanics for Engineering Students", 3rd Edition, Elsevier Butterworth-Heinemann Linacre House, Jordan Hill, Oxford OX2 8DP, 2013.
5. International GNSS Service (IGS): http://igscb.jpl.nasa.gov/.
6. P. Teunissen, O. Montenbruck, “Springer Handbook of Global Navigation Satellite Systems”, Springer International Publishing 2017.

7. Y. Jade Morton et. al." Position, Navigation, and Timing Technologies in the 21st Century: Integrated Satellite Navigation, Sensor Systems, and Civil Applications", Volume 1 and Wiley-IEEE Press 2021.

Web linkes: ---
Student's field trip: ---

COURSE SCHEDULE/OUTLINE/CALENDAR OF EVENTS

Week	Topic
1	Satellites orbit, two-body problem, proof of Kepler's laws
2	Equation of motion, orbit integration, Energy law, and different types of orbits.
3	Restricted three-body problem, the concept of Co-Moving frame, Jacobi constant, Lagrange points.
4	Lagrange's and Gaussian Perturbation Equations.
5	Orbits and constellations: Types of satellite orbits: LEO, MEO, and GEO, sun-synchronous, Geostationary orbit.
6	Coordinate systems in satellite geodesy: Basic concepts of coordinate systems in geodesy.
7	New conventions, different frames, and systems; ITRF, ICRF
8	GNSS solutions and SINEX standard format.
9	The ionosphere, foundational concepts, various ionospheric models, and mathematical methods to derive Total Electron Content (TEC) from GNSS data.
10	Ionospheric Models, IONEX format, international ionospheric products, satellites for ionospheric studies.
11	Relative positioning: a review of general concepts and development of the mathematical model of relative positioning.
12	Phase ambiguity resolution, ambiguity spaces, and Some ambiguity solution techniques such as ambiguity function, QIF, and LAMBDA.
13	PPP (Precise Point Positioning), the principles of PPP, Biases and errors in PPP.
14	PPP Observation equation, observation weighting, filter design and processing, online PPP services.

EVALUATION PROCEDURES AND GRADING CRITERIA

Assignments	-- points
Comprehensive Assignment	-- points (at max)
Mid-Term Exam	-- points
Final Exam	-- points
Total Points	-- points

Advanced Estimation Methods

BASIC INFORMATION

Place in curriculum, title and semester: core, Advanced estimation methods, S2
Number of credits: 3

COURSE PREREQUISITES

Adjustment theory, statistical test

COURSE CO-REQUISITES

TEACHERS

The person in charge: Dr. Hamid Mehrabi
Office location: Department of Geomatics Engineering, Faculty of Civil Engineering & Transportation, University of Isfahan, Isfahan, 81746-73441, Iran
Phone number: +983137935297
Homepage: https://engold.ui.ac.ir/~h.mehrabi/
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Other instructors: --

WEEKLY HOURS

Theory	Problem Solving	Laboratory	Guided learning
3 h	yes	---	---

COURSE OBJECTIVES

Advanced estimation techniques in geomatics sciences including advanced linear algebra methods, variance (covariance) components estimation and its application in geodesy, singular models and correct estimation methods (non-decimal) of parameters are discussed.

REQUIRED STUDENT RESOURCES

References:

1. P. J. G. Teunissen, D.G. Simons, C.C.J.M. Tiberius, "Probability and Observation Theory", Delft University of Technology, Delft University Press, 2008.
2. E. Grafarend, and F. Sanso, Editors, "Optimization and Design of Geodetic Networks", Springer, 1985.
3. A. R. Amiri-Simkooei, "Variance component estimation in linear models: theoretical and practical aspects on Global Positioning System", VDM Verlag Dr. Müller, 2010.
4. P. J. G. Teunissen, "Adjustment Theory: An introduction", Delft University of Technology, Delft University Press, 2000.

Web linkes: ---
Student's field trip: ---

COURSE SCHEDULE/OUTLINE/CALENDAR OF EVENTS

Week	Topic
1	Vector spaces, independence and dependence of vectors, basis and dimension of vector space, overlaooing, community and sum of vector spaces.
2	Matrices and matrix operators, derivative of matrices, range space and null space of a matrices, rank of a matrix.
3	The inverse of matrices, solution for the system of linear equations, triangular matrices and LDU decomposition, inverse of partitioned matrices.
4	Determinants of matrices, determined and positive matrix, Euclidean space and definition for norm and orthogonality of vectors, oblique and orthogonal projectors, adjustment solution as an orthogonal projector.
5	“vec” and “vh” operators, and Kronecker product, adjoint and permutation matrices, introduction of parameters in the stochastic model.
6	System of observation equations in the stochastic model, class of allowed weight matrices of stochastic model.
7	Covariance matrix of stochastic model, minimum variance components estimation, advantages of the method, special functional and stochastic models.
8	Negative variances problem, singular stochastic models, ill-conditioned stochastic models, the method applications.
9	The concept of singularity from the projecting point of view, singular value decomposition theorem, comprehensive inverse, left and right inverse, geometric expressions.
10	Comprehensive inverses of least squares, recursion, minimum norm, least squares norm, similarity transformation, calculation of datum matrix for inner constrain method, linear unbiased estimators in singular models.
11	The concept of non-negative least squares estimator, application of non-negative estimator in GNSS, the concept and calculation of success rate.
12	Rounding to the nearest integer, self-starting method, non negative least squares estimator.
13	The definition and shape of cache areas in non-negative estimates of parameters, invariance of non-negative least squares estimator with respect to non-singular allowed transformations.
14	Uncorrelation of phase ambiguities, introduction of Landa and network methods.

EVALUATION PROCEDURES AND GRADING CRITERIA

Assignments	-- points
Comprehensive Assignment	-- points (at max)
Mid-Term Exam	-- points
Final Exam	-- points
Total Points	-- points

Advanced Geodynamics

Basic Information

Place in curriculum, title and semester: core, Advanced geodynamics, S2
Number of credits: 3

Course prerequisites

Course co-requisites

Teachers

The person in charge: Dr. Hamid Mehrabi
Office location: Department of Geomatics Engineering, Faculty of Civil Engineering & Transportation, University of Isfahan, Isfahan, 81746-73441, Iran
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Email address: h.mehrabi@eng.ui.ac.ir
Other instructors: --

Weekly Hours

Theory	Problem Solving	Laboratory	Guided learning
3 h	--	---	---

Course Objectives

To understand the concepts of earth dynamic and the factors that influence it through modeling and conducting relevant calculations.

Required Student Resources

References:

1. H. Moritz and I. I. Muellar, "Earth Rotation: Theory and Observation", Ungar, New York,1987.
2. A. Brzezinski and S. Petrov, "High Frequency Atmospheric Excitation of Earth Rotation", IERS Technical Note, 28:53-60, 2000.
3. W.H. Munk and G.J.F. MacDonald, "The Rotation of the Earth. A Geophysical Discussion", Cambridge University Press, New York, 1960.
4. S. I. Karato, "Deformation of Earth Materials: An Introduction to the Rheology of Solid Earth", Cambridge University Press, 2008.
5. P. Vanicek and E. J. Krakiwsky," Geodesy the Concepts", North-Holland, 1986.
6. G. Ranalli, "Rheology of the Earth", Chapman & Hall, 1995.
7. Z. Martinec, "Continum Mechanics for Geophysicist and Geodesists Part I: Basic Theory", Technical Report, Universität Stuttgart, 1999.
8. D. Wolf, "Continum Mechanics in Geophysics and Geodey: Fundamental Principles", Universität Stuttgart, 2003.

9. D. L. Turcott and G. Schubert, “Geodynamics”, Cambridge University Press, 3rd Edition 2014.
10. Gerya, Taras. Introduction to numerical geodynamic modelling. Cambridge University Press, 2019.

Web linkes: ---
Student's field trip: ---

COURSE SCHEDULE/OUTLINE/CALENDAR OF EVENTS

Week	Topic
1	Deformation, strain and stress analysis, relationship between these two groups, Poisson's ratio.
2	Young's modulus, Lame constants, Euler and Lagrangian coordinate systems.
3	Finite difference and finite element methods in strain analysis, use of parameters (length and angle) in strain analysis.
4	Numerical deformation criteria extracted from strain tensor.
5	Linear elasticity equations, special states of stress and strain.
6	The moon and sun tidal phenomena: the potential of tides on land.
7	sea tides, Love numbers, effects of tides in geodesy, Load numbers.
8	Tectonic movements: global models, plate movement mechanism, plate collision boundary.
9	Orogeny, blue hole, mid-oceanic ridge, faulting and deformation phenomena in faults.
10	Triple junction, the condition for forming a stable triple junction.
11	Numerical solution for problems related to triple junction.
12	Earthquake: earthquake magnitude and intensity, measurement scales.
13	Focal mechanism, internal and surface waves.
14	Geodynamic changes caused by the earth rotation, polar motion for rigid and non-rigid earth without external torque.
15	Polar motion for rigid earth with external torque, Euler and Chandler earth rotation periods.

EVALUATION PROCEDURES AND GRADING CRITERIA

Assignments	-- points
Comprehensive Assignment	-- points (at max)
Mid-Term Exam	-- points
Final Exam	-- points
Total Points	-- points

Time Series Analysis

Basic Information

Place in curriculum, title and semester: core, Time series, S2
Number of credits: 3

Course prerequisites

Statistics, adjustment theories, Estimation methods

Course co-requisites

Stochastic Processes, Advanced Estimation methods

Teachers

The person in charge: Dr. Hamid Mehrabi
Office location: Department of Geomatics Engineering, Faculty of Civil Engineering & Transportation, University of Isfahan, Isfahan, 81746-73441, Iran
Phone number: +983137935297
Homepage: https://eng.ui.ac.ir/~h.mehrabi
Email address: h.mehrabi@eng.ui.ac.ir
Other instructors: Fateme Esmaeili

Weekly Hours

Theory	Problem Solving	Laboratory	Guided learning
3 h	yes	---	---

Course Objectives

To learn advanced techniques of time series analysis and to develop skills in mathematical modeling of time series in various applications of geomatic sciences.

Required Student Resources

References:

1. Laine, M. (2020). Geodetic time series analysis in Earth sciences. Cham: Springer, 139-156.
2. Amiri-Simkooei, A. R., Tiberius, C. C., & Teunissen, P. J. (2007). Assessment of noise in GPS coordinate time series: methodology and results. Journal of Geophysical Research: Solid Earth, 112(B7).
3. Amiri-Simkooei, A. R. "Noise in multivariate GPS position time-series." Journal of Geodesy 83 (2009): 175-187.
4. Ghil, M., Allen, M. R., Dettinger, M. D., Ide, K., Kondrashov, D., Mann, M. E., ... & Yiou, P. (2002). Advanced spectral methods for climatic time series. Reviews of geophysics, 40(1), 3-1.
5. Gruszczynska, Marta, et al. "Deriving common seasonal signals in GPS position time series: By using multichannel singular spectrum analysis." Acta Geodynamica et Geomaterialia 14.3 (2017): 267-278.

6. Khazraei, S. M., and A. R. Amiri-Simkooei. "On the application of Monte Carlo singular spectrum analysis to GPS position time series." Journal of Geodesy 93 (2019): 1401-1418.

Web linkes: ---
Student's field trip: ---

COURSE SCHEDULE/OUTLINE/CALENDAR OF EVENTS

Week	Topic
1	Introducing main references in the field of geodetic time series analysis, an introduction of time series, stationary time series versus non stationary time series.
2	Some examples of time series in geodesy and their unique features and related papers.
3	Concept of functional model and stochastic model, functional model and stochastic model components in GNSS time series.
4	Stochastic noise model, different types of noise models in time series.
5	LS-VCE method, noise components estimation.
6	Power law noise in GNSS stations time series, producing different noise by defining the covariance matrix (algorithm).
7	Detection of realistic noise model for time series.
8	Parametric methods versus non-parametric methods, least square Harmonic Estimation (LS-HE), trend and harmonics estimation for time series.
9	Harmonic behaviors detection and their frequencies in time series, Multivariate analysis of time series.
10	Modulated harmonic analysis of time series, Offset and offsets detection in time series.
11	Introduction of non-parametric methods, theory of singular spectrum analysis (SSA) method.
12	Monte Carlo singular spectrum analysis (MCSSA), Multivariate versus univariate analysis.
13	Introduction to wavelet method, continuous and discrete wavelets, spectrogram.

EVALUATION PROCEDURES AND GRADING CRITERIA

Assignments	2 points
Comprehensive Assignment	2 points (at max)
Mid-Term Exam	4 points
Final Exam	12 points
Total Points	20 points

Elective Courses

Advanced Physical Geodesy

Basic Information
Place in curriculum, title and semester: core:Advanced physical geodesy, S2
Number of credits: 3

COURSE PREREQUISITES

COURSE CO-REQUISITES

TEACHERS

The person in charge: Dr. Jamal Asgari
Office location: Department of Geomatics Engineering, Faculty of Civil Engineering & Transportation, University of Isfahan, Isfahan, 81746-73441, Iran
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Homepage: https://engold.ui.ac.ir/~asgari/
Email address: asgari@eng.ui.ac.ir
Other instructors: --

WEEKLY HOURS

Theory	Problem Solving	Laboratory	Guided learning
3 h	--	---	---

COURSE OBJECTIVES

The objective of this course is to study techniques for modeling and calculating Earth's gravity field, as well as solving related boundary problems.

REQUIRED STUDENT RESOURCES

References:

1. J. Yi Guo, “Physical Geodesy: A Theoretical Introduction”, Springer, 2023
2. N. Sneeuw, “Physical Geodesy”, Lecture Note, Institute of Geodesy, University of Stuttgart, 2006.
3. B. Hofmann-Wellenhof and H. Moritz,” Physical Geodesy”, Springer, 2006.
4. H. Moritz, “Advanced Physical Geodesy”, Wichmann, 1980.
5. F. Sansò,” Geodetic Boundary Value Problems in View of the One Centimeter Geoid”, Springer, 1997.
6. P. Vanicek and E. J. Krakiwsky,” Geodesy the Concepts”, North-Holland, 1986.
7. W. Torge, “Gravimetry”, De Gruener, Berlin, 1989.

Web linkes: ---
Student's field trip: ---

COURSE SCHEDULE/OUTLINE/CALENDAR OF EVENTS

Week	Topic

1	Molodensky boundary value problem: Molodensky vector boundary value problem.
2	Molodensky scalar boundary value problem, solution methods.
3	Surface vertical deflection components, Brovar-type solution, solution with the analytical transfer.
4	Stokes-Helmert method: topographic mass balance, formulation of the fundamental problem of physical geodesy.
5	Estimation of Helmert gravity anomalies on the earth's surface.
6	The Bruns formula, calculation of atmospheric and topographical effects.
7	The boundary value problem of Dirichlet, reference field, and spheroid in Helmert gravity space.
8	Stokes boundary value problem in Helmert gravity space, indirect effect.
9	Boundary value problem with known boundary: linearization of boundary value with known boundary.
10	Nonlinear boundary value problem with excessive information and with known boundary.
11	Reference gravity field, continuous Abel-Poisson integral for differential quantities, gravimetric boundary value problem, satellite altimetry. Geoid derived from satellite altimetry as boundary information.
12	Numerical calculations in physical geodesy: two-dimensional Fourier transform, collocation theory.

EVALUATION PROCEDURES AND GRADING CRITERIA

Assignments	-- points
Comprehensive Assignment	-- points (at max)
Mid-Term Exam	-- points
Final Exam	-- points
Total Points	-- points

Atmosphere In Space Geodesy

Basic Information

Place in curriculum, title and semester: core, Atmosphere in Space Geodesy, S2
Number of credits: 3

Course prerequisites

Course co-requisites

Teachers

The person in charge: Dr. Jamal Asgari
Office location: Department of Geomatics Engineering, Faculty of Civil Engineering & Transportation, University of Isfahan, Isfahan, 81746-73441, Iran
Phone number: +98-37935290
Homepage: https://engold.ui.ac.ir/~asgari/
Email address: asgari@eng.ui.ac.ir
Other instructors: --

Weekly Hours

Theory	Problem-Solving	Laboratory	Guided learning
3 h	yes	---	---

Course Objectives

This course focuses on understanding the theoretical foundations of atmospheric delay and how different space geodesy methods model the errors caused by this phenomenon.

Required Student Resources

References:

1. G. Seeber, "Satellite Geodesy: Foundations, Methods, and Applications", 2nd Edition. Walter de Gruyter, Berlin New York, 2003.
2. O. J. Sover and John L. Fanselow," Astrometry and Geodesy with Radio Interferometry: Experiments, Models, Results", Review of Modern Physics, Vol. 70, No. 4, October 1998.
3. J Böhm and H. Schuh (Editors), "Atmospheric Effects in Space Geodesy", Springer, 2013.
4. F. Kleijer, "Tropospheric Modeling and Filtering for Precise GPS Leveling", PhD thesis, TU Delft, 2004.
5. H. Kraus, "Die Atmosphäre der Erde - Eine Einführung in die Meteorologie ", 3rd Edition, Springer, ISBN 3-540-20656-6, 2004.
6. J. M. Wallace and P.V. Hobbs, "Atmospheric Science: An Introductory Survey", 2nd Edition, Academic Press, 2006.

7. D. D. Wijaya," Atmospheric correction formulae for space geodetic techniques", PhD thesis, Graz University of Technology, Institute of Engineering Geodesy and Measurements Systems, Shaker Verlag, 2010.
8. Y. Jade Morton et. al." Position, Navigation, and Timing Technologies in the 21st Century: Integrated Satellite Navigation, Sensor Systems, and Civil Applications", Volume 1 and Wiley-IEEE Press 2021
9. P. Teunissen, O. Montenbruck, "Springer Handbook of Global Navigation Satellite Systems", Springer International Publishing 2017.

Web linkes: ---
Student's field trip: ---

COURSE SCHEDULE/OUTLINE/CALENDAR OF EVENTS

Week	Topic
1	Effect of the ionosphere on microwave waves: phase and group velocity
2	Ionospheric refractive index, ionospheric delay, and how to deal with it.
3	Physics of troposphere: structure of the troposphere
4	Refraction, Dispersive, and non-dispersive mediums.
5	Data sources for meteorological parameters: radiosondes, radiometers.
6	Numerical weather models, standard atmospheric models.
7	Tropospheric delay modeling: total tropospheric delay.
8	Total zenith delay, mapping functions, gradient models.
9	Direct ray tracing: Eikonal equation in the general case, Eikonal equation in the spherical coordinate system, two-dimensional and three-dimensional methods.
10	The effect of the horizontal gradient on the ray-tracing results, the main components of a typical ray-tracing method.
11	Atmospheric pressure loading: changes in surface pressure and deformation of the Earth's crust.
12	Atmospheric pressure loading modeling, effect on space geodetic measurements.
13	The effect of the atmosphere on gravity field missions.
14	The effect of the atmosphere on the earth's rotation.

EVALUATION PROCEDURES AND GRADING CRITERIA

Assignments	-- points
Comprehensive Assignment	-- points (at max)
Mid-Term Exam	-- points
Final Exam	-- points
Total Points	-- points

Inertial Navigation Systems And GNSS/INS Integration

BASIC INFORMATION

Place in curriculum, title and semester: core, Inertial Navigation Systems and GNSS/INS Integration, S2
Number of credits: 3

COURSE PREREQUISITES

COURSE CO-REQUISITES

TEACHERS

The person in charge: Dr. Jamal Asgari
Office location: Department of Geomatics Engineering, Faculty of Civil Engineering & Transportation, University of Isfahan, Isfahan, 81746-73441, Iran
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Other instructors: --

WEEKLY HOURS

Theory	Problem Solving	Laboratory	Guided learning
3 h	yes	---	---

COURSE OBJECTIVES

This course tackles the math and physics behind inertial navigation systems (INS), exploring the challenges of setting them up and how they can be combined with the Global Navigation Satellite System (GNSS) for a more complete navigation solution.

REQUIRED STUDENT RESOURCES

References:

1. Jekeil, "Inertial Navigation Systems with Geodetic Applications", Walter de Gruyter, Berlin, New York, 2001.
2. M.S. Grewal, L.R. Weill, and A.P. Andrews, "Global Positioning Systems, Inertial Navigation, and Innegration", John Wiley & Sons, Inc., 2001.
3. P.D. Groves, "Principles of GNSS, Inertial, and Multisensor Integrated Navigation Systems", Artech House, 2008.
4. R.M. Rogers, "Applied Mathematics in Integrated Systems", AIAA Education Series 3rd Edition, 2007.
5. P. Aggarwal, Z. Syed and A. Noureldin, "MEMS-Based Integrated Navigation (GNSS Technology and Applications) ", Artech House, 2010.
6. D. Titterton and J. Weston, "Strapdown Inertial Navigation Technology", 2nd Edition, IEE Radar, Sonar, Navigation & Avionics, 2005.

7. Y. Jade Morton et. al.” Position, Navigation, and Timing Technologies in the 21st Century: Integrated Satellite Navigation, Sensor Systems, and Civil Applications”, Volume 1 and Wiley-IEEE Press 2021
8. P. Teunissen, O. Montenbruck, “Springer Handbook of Global Navigation Satellite Systems”, Springer International Publishing 2017.

Web linkes: ---
Student's field trip: ---

COURSE SCHEDULE/OUTLINE/CALENDAR OF EVENTS

Week	Topic
1	Applications of inertial systems and GNSS/INS integration in geomatics,
2	Coordinate systems and transformation, Inertial, ECEF, and navigation frames, transformations: Direction cosines, Euler angles, quaternion, axial vectors, angular rate, differential equations of transformations.
3	Inertial Measurement Units (IMU), Gyroscopes: mechanical gyroscopes, optical gyroscopes.
4	Laser ring gyroscopes and their errors, Fiber Optic gyroscopes and their errors.
5	Accelerometer, Accelerations in Non-Inertial Frames, Pendulous Accelerometer, Vibrating Element Dynamics.
6	Piezoelectric accelerometers, accelerometers and gravity measurement in geodesy.
7	Inertial Navigation Systems, INS mechanizations, Space stabilized mechanization, Local-Level Mechanization: Schuler tuning, Wander Azimuth Mechanization.
8	Strapdown mechanization: Numerical Determination of the Transformation Matrix.
9	Navigation equations: navigation equations in different frames: i-Frame, e-Frame, n-Frame, w-Frame, Numerical integration of navigation equations.
10	System Error Dynamics, investigating the effect of gravity in INS, The effect of IMU errors.
11	INS Initialization and Alignment, Coarse Alignment and Fine Alignment.
12	Integration of GNSS and INS, explaining the advantages and disadvantages of each system and the importance of integration.
13	Decentralized integration, centralized integration, applications of integration.
14	Moving-base gravimetry, introduction, Gravity from GPS/INS integration, Gravitation from Accelerometry.

EVALUATION PROCEDURES AND GRADING CRITERIA

Assignments	-- points
Comprehensive Assignment	-- points (at max)
Mid-Term Exam	-- points
Final Exam	-- points
Total Points	-- points

RADAR Altimetry & Interferometry

BASIC INFORMATION

Place in curriculum, title and semester: core, RADAR Altimetry & Interferometry, S2
Number of credits: 3

COURSE PREREQUISITES

COURSE CO-REQUISITES

TEACHERS

The person in charge: Dr. Hamid Mehrabi
Office location: Department of Geomatics Engineering, Faculty of Civil Engineering & Transportation, University of Isfahan, Isfahan, 81746-73441, Iran
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Homepage: https://engold.ui.ac.ir/~h.mehrabi/
Email address: h.mehrabi@eng.ui.ac.ir
Other instructors: --

WEEKLY HOURS

Theory	Problem Solving	Laboratory	Guided learning
3 h	yes	---	---

COURSE OBJECTIVES

To present the principles of altimetry and radar interferometry methods and their geometrical features and correct the related errors and explain how to process the data obtained from these methods.

REQUIRED STUDENT RESOURCES

References:

1. V.B.H. Gini Ketelaar, "Satellite Radar Interferometry: Subsidence Monitoring Techniques", Springer, 2009.
2. M.I. Skolnik, “Introduction to Radar Systems”, 3rd Edition, McGraw-Hill, 2002.
3. N. El-Sheimy, C. Valeo and A. Habib, “Digital Terrain Modeling: Acquisition, Manipulation and Applications”, Artech House Publishers, 2005.
4. R.F. Hanssen, "Radar Interferometry: Data Interpretation and Error Analysis", Springer, 2001.
5. M. K. Bert “Radar interferometry: persistent scatterers technique”. The Netherlands: Springer. 2006.
6. D. Dzurisin, “Volcano deformation: new geodetic monitoring techniques”. Springer Science & Business Media, 2006.

Web linkes: ---

Student's field trip: ---

COURSE SCHEDULE/OUTLINE/CALENDAR OF EVENTS

Week	Topic
1	Introduction: The purpose of altimetry, the history of radar altimetry satellites
2	Specifications and information of radar altimetry satellites: existing satellites.
3	Altimetry data: types of data and differences.
4	Principles of radar altimetry measurement: calculating the points height from the measurements of radar altimetry satellites.
5	Necessary corrections to calculate the correct altitude: geoid correction, orbit correction, ionosphere and troposphere correction, etc.
6	Calculations of corrections in the altimetry method, principles of aerial triangulation and the formation of bundle adjustment in altimetry, accuracy estimation.
7	Estimation of the measured points geographic longitude and latitude.
8	Digital topography map of sea level points and moors, comparison with digital map obtained from GPS.
9	Flagging: definition and types, determining the best combination of flags in lands and sea.
10	Principles of interferometry, radar altimetry, instruments and space missions.
11	Radar interferometry equations, errors (factors and geometric model of errors), solving phase ambiguity and jumps.
12	The applications of radar interferometry in determining height and topography, land subsidence and landslides, changes determination.

EVALUATION PROCEDURES AND GRADING CRITERIA

Assignments	-- points
Comprehensive Assignment	-- points (at max)
Mid-Term Exam	-- points
Final Exam	-- points
Total Points	-- points