COURSE OF STUDY: Potential Geophysical Fields

ACADEMIC YEAR: 2025-2026

ACADEMIC SUBJECT: Master Degree in Geological and Geophysical Sciences

General information	
Year of the course	2nd
Academic calendar (starting and ending date)	2st March 2026 – 15th June 2026
Credits (CFU/ETCS):	64
SSD	GEOS-04/B
Language	Italian
Mode of attendance	Frontal lessons with exercises in classroom and in the field

Professor/ Lecturer	
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Virtual room	https://teams.microsoft.com/l/team/19%3A0d940377a6ca43d6aa89888e9b62972f%40thread.tacv2/conversations?groupId=dedd3f28-7a34-4bd1-9b2d-c5e6b3761bef&tenantId=c6328dc3-afdf-40ce-846d-326eead86d49
Office Hours (and modalities: e.g., by appointment, on line, etc.)	Monday 11:00 – 13:00 or by appointment at agreed times.

Work schedule			
Hours			
Total	Lectures	Hands-on (laboratory, workshops, working groups, seminars, field trips)	Out-of-class study hours/ Self-study hours
64	48	16	111
CFU/ETCS			
7	6	1	

Learning Objectives	Acquisition of general and applicative knowledge on the earth's gravity and magnetic field.
Course prerequisites	Basic knowledge of Earth Physics, Mathematics, Physics

Teaching strategie	Lectures will be supported by PowerPoint presentations. Practical exercises will be carried out, including instrumental measurements in the field and data processing and interpretation using computer programmes. Students will be encouraged to discuss any problems encountered when completing the tests, as well as the reasons for any failures, with each other and with the teacher. This will help them to identify the main possible causes of errors that may occur in the data analysis procedures.

Expected learning outcomes in terms of	
DD1 Knowledge and understandingon:	• Knowledge and understanding of the following topics: General characteristics of the gravity field, the Earth's magnetic field and the methods of analysis of their different components. Principles and methods of the acquisition of gravimetric and magnetometric data, aimed at defining, through their treatment with advanced quantitative approaches, the physical-geometric characteristics of geological bodies and/or artificial structures, as part of the study of geological structures, research and management of geo-resources and the location of natural cavities and buried artifacts. This knowledge will be acquired through theoretical lessons.
DD2 Applying knowledge and understanding on:	• Aware application of acquired knowledge to: performing gravimetric measurements and taking part in the acquisition of magnetometric data, as well as analysing the results and interpreting them. These skills will be acquired through practical experiences and exercises of data processing and numerical modeling.
DD3-5 Soft skills	• DD3: Making informed judgments and choices in: identifying the most suitable investigation techniques for the study of geological structures, for the research and management of geo-resources, for the localization of natural cavities and buried artifacts. These skills will be developed during classroom exercises. • DD4: Communicating knowledge and understanding by: developing the aptitude to expose the fundamental principles and concepts of the study themes and the ability to describe techniques and procedures for acquiring, processing and interpreting data with clarity and proper language usage, both within working groups comprising different areas of expertise and to the general public. These skills will be practised through dialogue with teachers and classmates during lessons and exercises. • DD5: Capacities to continue learning by*:* developing the ability to deepen the understanding of complex concepts, elaborating autonomous reasoning aimed at identifying the links and differences between the various themes of the course..

Syllabus	
Content knowledge	The course provides 6 CFU from frontal lesson and 1 CFU from exercises including experiences of measurement in the field and numerical tests in classroom. The subjects of frontal lessons are organized according two main parts

	dealing with Gravimetry and Geomagnetism, in turn subdivided into the following sub-sections. PART I GRAVIMETRY 1) NEWTON'S LAW AND GRAVITATIONAL FIELD: Force and gravitational acceleration. Gravitational potential. Gauss's law. Divergence theorem. Poisson equation. Laplace equation. Upward and downward continuation of the gravitational field. Green equivalent layer. 2) GRAVITY FIELD AND EARTH SHAPE: Definition of gravity: gravitational and centrifugal acceleration. Gravity potential and its description in terms of spherical harmonics. Geoid. Approximate models: spheroid, ellipsoid. Geodetic Reference Systems. Normal gravity and international formula of gravity. 3) MEASUREMENT INSTRUMENTS: Absolute gravimeters: ballistic measures. Relative measurements: linear and astatic gravimeters. The Lacoste & Romberg gravimeter. 4) DATA ACQUISITION PROCEDURES: Connection to absolute gravity networks. Gravity meter calibration. Planning of a gravimetric measurement campaign: choice of the location of the stations, positioning, measurement sequence arrangement. Processing of the measures for calculating the observed gravity: calibration factor application, tripod height correction, tide correction, Eötvös correction and drift correction. 5) CALCULATION OF ANOMALIES: Density of the rocks. Calculation of Bouguer anomalies: free air correction and Faye anomalies; Bouguer and terrain correction. Estimate of the correction density: Nettleton method, Parasnis method. Physical meaning of the Bouguer anomalies. Isostatic anomalies: calculation of the isostatic correction according to the Pratt and Airy models. 6) SEPARATION OF ANOMALIES AND FILTERINGS: Relationships between the characteristics of anomalies and their sources. Anomalous mass. Depth, horizontal size of the sources, amplitude, wavelength and horizontal gradient of the anomalies. Regional field and residual anomalies. Graphic filtering. Moving average, Griffin method and grid operators. Polynomial method. One- and bi-dimensional Fourier transform. General problems of numerical filtering. Vertical derivatives and upwards and downwards continuation. 7) INTERPRETATION OF ANOMALIES: Qualitative interpretation. Interpretative ambiguity. Elementary geometric models and half-width method: sphere, infinite horizontal cylinder. Direct 2D, 2D and 1/2 and 3D modelling. Example of inversion algorithm: GRAV3D.

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	PART II GEOMAGNETISM 1) GENERAL PRINCIPLES OF MAGNETISM: Description of magnetic interactions: classic approach, modern approach and relative units of measurement. Magnetising field, magnetic induction field and magnetisation intensity. Scalar magnetic potential. Laplace equation. Poisson theorem. 2) MAGNETIC PROPERTIES OF THE MATTER: Diamagnetism. Paramagnetism. Ferromagnetism, antiferromagnetism and ferrimagnetism. Magnetic domains. Rock magnetisation: induced and remanent magnetisation. Natural remanent magnetisation. Primary magnetisations: thermo-remanent, chemical, debris magnetisation. Secondary magnetisations: isotherm, piezo-remanent and viscose magnetisation. Koenisberger ratio. 3) THE TERRESTRIAL MAGNETIC FIELD: General characteristics: intensity, inclination, declination, horizontal and vertical components. Representation of the Earth's magnetic field by spherical harmonics. Core field: dipolar and non-dipolar field. IGRF and normal field. Crustal field and magnetic anomalies. Field of external origin: diurnal variation, magnetic storms and sub-storms, pulsations. Temporal variations of the nuclear field: variations of the dipolar and non-dipolar fields, geomagnetic jerks. Paleomagnetism: measurements of remanent magnetisation and paleo-intensity; virtual geomagnetic poles, paleomagnetic poles, hypothesis of the geocentric axial dipole and polarity reversals. Hypothesis on the origin of the nuclear magnetic field. Introduction to magnetofluid dynamics: Navier-Stokes equation, magnetic induction equation. Interpretative models. 4) MAGNETIC FIELD MEASURING INSTRUMENTS: Magnetic field measurement instruments. Flux-gate magnetometer. Proton magnetometer. Optical pumping magnetometer. 5) MAGNETOMETRIC MEASUREMENTS: Measurements of the elements of the Earth's magnetic field: geomagnetic observatories. Detail magnetometric measurements: measurement procedures. Gradient measurements. Measures on large areas: aeromagnetic and marine surveys. Data processing: corrections for diurnal variation and for core field. Signal filtering and treatment: downwards and upwards continuation, first and second derivatives, transformation into pseudo-gravity and reduction to the pole. 6) DATA INTERPRETATION: Qualitative interpretation: shape, amplitude, wavelength, horizontal gradients and relationships with geological structures. Quantitative interpretation. Simplified geometric models: uniformly magnetised sphere. Depth estimation from half-width and slope calculation. Spector and Grant method. Direct 2D and 3D modeling. 7) CHARACTERISTICS OF THE MAGNETIC FIELD IN ITALY: Italian magnetic net.

	Calculation of the normal field coefficients. Magnetic anomalies map from land and sea measurements. Aeromagnetic map of Italy. The exercises will focus on the following experiences 1) Execution on the ground of gravimetric measurements. 2) Processing of data acquired on the ground for calculating the observed gravity (conversion by calibration factor, tripod height corrections, tide and drift corrections). 3) Use of a program to calculate Bouguer anomalies and application to a case study. 4) Filtering of a Bouguer anomalies for a case study. Use of a program for the spectral analysis and filtering of a Bouguer anomaly map; graphic representation by means of a GMT graphic package. 7) Inversion of residual anomalies for a case study: use of the GRAV3D software package to obtain an interpretative model of Bouguer anomalies. 8) Demonstration of the use of an optical pumping magnetometer, data download and preliminary processing.
Texts and readings	Sharma P.V. (1997): Environmental and engineering geophysics. Cambridge University Press. Telford W.M., Geldart L.P & Sheriff R.E. (1990): Applied Geophysics. Cambridge. University Press Butler R.F. (2004): Paleomagnetism: Magnetic Domal testi devono essere integrati con le dispense di lezione, i software distribuiti nelle esercitazioni e le pagine web suggerite dal docente durante le lezioni.ins to Geologic Terranes. University of Portland http://www.pmc.ucsc.edu/~njarboe/pmagresource/ButlerPaleomagnetismBook.pdf
Notes, additional materials	Textbook consultation will be integrated with lesson notes and suggestions of website to browse.
Repository	Lecture notes, copy of PowerPoint presentation slides and software distributed during the exercises

Assessment	
Assessment methods	The final evaluation will be based mainly on the results of an oral exam, during which the student will be invited to illustrate the fundamental properties of the gravity field and the earth's magnetic field, also in comparative form, and to describe the methods of acquisition, processing and interpretation of gravimetric and magnetometric data. The overall judgment of students will take into account the assiduity of the lesson attendance, the active participation to exercises and the effectiveness in facing the problems proposed. The accuracy of communication both in the discussion of the lesson topics and in the knowledge application to tests,

	will also be evaluated.
Assessment criteria	• *Knowledge and understanding* The student must demonstrate his comprehension of the main characteristics of the gravity field and the Earth's magnetic field by demonstrating to master the understanding of the properties of the different potential fields (gravimetric and magnetic) and to recognize their analogies and differences. The level of knowledge achieved and the mastery of the fundamental concepts will be verified through the discussion of the study topics during an oral exam. • *Applying knowledge and understanding* The student must be able to use the basic knowledge acquired to identify the correct procedures to be followed in the acquisition, processing and interpretation of the data. The skills acquired will be verified through practical tests performed during the exercises, also assessing the ability of a dialectical interaction with the course colleagues. • *Autonomy of judgment* The student must be able to identify the most suitable methodological choices for solving proposed problem. The achievement of this objective will be verified through the results of tests carried out during the exercises and through the proposition, during the oral exam, of problems requiring the application of gravimetric and magnetometric investigations, for which the student must prove to be able to identify the best procedures to deal with them. • *Communicating knowledge and understanding* The student must be able to describe clearly and with proper language usage all the topics covered during the course, without giving cause for ambiguity or misunderstandings. She/he must also be able to dialogue and relate to other students. The verification of these skills will be assessed on the basis of the language propriety shown discussing the cases proposed during tests on knowledge application and exposing the subjects of the oral exam. • *Capacities to continue learning* The student must be able to enrich the understanding of the topics through individual study in-depth, aimed at acquiring further knowledge starting from the base of the content transmitted during the course. The level reached in this capacity will be verified through the discussion of the exam topics.

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Final exam and grading criteria	During the exam, evidence of a lack of understanding of fundamental concepts may result in the exam being interrupted and the student being referred to a later session. The ability to succeed in completing the tests during the exercises will be one of the elements that will contribute to define the exam mark. If the student, at the end of his/her training course, does not demonstrate to have acquired the necessary skills, this gap may result in the failure to pass the exam and the need for the student to retake it at a later date. Demonstration of a proactive ability in finding solution of specific problems will be considered a factor determinant in assigning a high final mark. The insufficient mastery of the language propriety may result in a penalization of the final mark, with the exclusion of the possibility of achieving the maximum mark. The demonstration of an acquired ability to broaden one's knowledge with an autonomous learning path will be acknowledged through the attribution of the maximum mark with honors.
Further information	
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