M. TECH. in GEOLOGICAL TECHNOLOGY & PH.D. in EARTH SCIENCES

Department of Earth Sciences
Indian Institute of Technology, Kanpur

CREDIT DISTRIBUTION

COURSE STRUCTURE

COURSE CONTENTS

A brochure

OVERVIEW OF THE COURSE STRUCTURE

TABLE 1: Course structure and distribution of credits in M. Tech. Program

Min. Total Credits	Min. Credit Through Course Work	Min. Credit Through Research	Min. Number of Courses	Min. Duration	Max. Duration
144	72	72	08	4 Semesters	4 years

TABLE 2: Course structure and distribution of credits in Ph.D. Program

Academic Program	Min. Credit Requirements	Min. Credit Through Coursework	Min. Credit Through Research work	Minimum Duration	Maximum Duration
Ph.D. with M.Tech	144	72 (4 courses)	72	4 semesters	6 years
Ph.D. with master's degree except M.Tech	180	72 (6 courses)	72	5 semesters	6 years
Ph.D. with bachelor's degree	216	72 (8 courses)	72	6 semesters	7 years

- There are **two compulsory courses** for Ph.D. students:
  - Introduction to profession and communication skills in Earth Sciences.
  - PG Seminar in Earth Sciences.
- The Ph.D. students should opt only for **PG-level courses**.
- They may opt for courses in other departments based on the supervisor's recommendation.
- Ph.D. students must finish with the required course credits and CPI (>7.0) before appearing for the Comprehensive examination.

  Note: These are minimum requirements.

  Note: One can also opt for S/X mode and/or Audit mode courses.

REGISTRATION FOR COURSES

- A student is required to register for semester-I, Semester –II and Summer term for each academic year.
- The normal semester load is defined as the equivalent of 36 credits. For a well-merited case, the SPGC may permita student to register for a maximum of 45 credits or a minimum of 27 credits.
- A student is required to register in the summer term for up to a maximum of half the normal semester load (i.e., 18 credits) and a minimum of 9 credits.

  Registration involves –
  - Preregistration through PINGALA portal for the courses/thesis credits that he/she intends to pursue in that semester/term.

- Payment of fees for that semester/term and clearance of any outstanding dues, and signing the registration roll with the office of the Dean of Students Affairs (DOAA).

TABLE 4: Semester-wise course distribution for M.Tech degree

Semester I (4x9=36 credits) **C1**: Mathematics for Earth Sciences. **C2**: Remote Sensing & GIS for Geo-resource evaluation. **C3**: Introduction to Profession & Communication Skills in Earth Sciences. **E1** : Elective **E2** : Elective	**Semester II (4x9 = 36 credits)** **C4**: Geophysical methods. **C5**: PG seminar in Earth Sciences. **E3**: Elective **E4**: Elective **E5**: Elective
Semester III (36 credits) M TECH THESIS (36 credits)	**Semester IV (36 credits)** M TECH THESIS (36 credits)

***C: Compulsory Course, E: Elective Course**

- **M.Tech students should register for the course (PG seminar in Earth Sciences) for at least one semester, and Ph.D. students should register for two semesters**.

TABLE 5: List of offered Elective Courses

1. Active Tectonics and Paleoseismology	12. Mineral Resource Exploration
2. Advanced Structural Geology.	13. Natural Hazards
3. Advance Metamorphic Petrology.	14. Non-Traditional Stable Isotope Geochemistry
4. Applied Hydrogeology.	15. Physics of Earthquakes
5. Applied sedimentology and Basin Analysis.	16. Planetary Geomorphology: Processes and Landforms
6. Aqueous Geochemistry.	17. Potential field theory in applied geophysics
7. Experimental Rock mechanics and Rock physics	18. River Science
8. Geodynamics.	19. Rock Magnetism
9. Geology and Geochemistry of petroleum.	20. Seismic Exploration & Subsurface Imaging
10. Instrumentation in Earth Sciences.	21. Solid Earth Geophysics
11. Isotope Geochemistry and Applications.	22. Quaternary Geology and Tectonic Geomorphology

*** Ph.D. students can take any courses mentioned above as per their availability in the course schedule.**

PLEASE REFER TO IIT KANPUR PG MANUAL FOR ACADEMIC REQUIREMENTS

COURSE CONTENTS

Active Tectonics and Paleoseismology (ES659) [9 credit]

Course content: Crustal deformation and earthquakes; Significance of seismicity; Identification of Prehistoric Earthquakes based on Primary and Secondary signatures preserved in landforms and sediment succession; Interpretation and Identification of Active Fault and associated Tectonic Landforms – Photogeologic Mapping, on-fault and off-fault landforms, identification and mapping of active faults and associated landforms in field, structural analysis of active faults & its implication to regional scale tectonics; Field Techniques in Paleoseismology, quantification of active fault scarp by precise mapping, identification of old (prehistoric) earthquake by trenching, mapping of deformed sedimentary succession by faulting, estimation of net displacement during single event, slip rate, magnitude of historic earthquake, recurrence interval, and prediction of future earthquake if possible; Identification and mapping of secondary effects due to strong seismic shaking – Identification of paleo-liquefaction features; Dating techniques; Correlation of paleoseismic data with existing geodetic and geophysical data; Delineation of seismogenic faults. Paleo-tsunami geology – Identification of Paleo-tsunami and Mega-subduction zone earthquakes signatures in the coastal region along subduction zones; Understanding land-level change caused by major earthquakes; decoupling the role of climate and tectonics; Understanding the effect of near-field and far-field earthquakes from stratigraphic records; effects of near-field and far-field tsunami.

Advanced Structural Geology (ES654) [9 credit]

Course Content: Introduction and methods of quantitative Structural Geology; Force and stress fields in Earth; Displacement and strain; Stress and Strain tensors; Mohr Circles; Geological analysis of field data (stereographic analysis and cross section construction); Strain analysis from deformed rocks; Stress-Strain-Time relationship under different conditions; Failure Mechanism; Deformation mechanisms and Rheology of cataclasis, crystal-plasticity and dissuasive mass transfer; Role of fluids and Fluid flow; Deformationin Brittle, Ductile and Brittle-Ductile transition; Structural anatomy and strength profile of tectonic boundaries; Applications.

Advance Metamorphic Petrology (ES662) [9 credit]

Course Content: Basics of petrology; Rock classifications; Structures and textures of rocks; Metamorphic Facies; Magmatism and metamorphism at various tectonic settings with associated rock-types and mineral assemblages. Electron microprobe, EPMA data processing, Ideal mixing activity, Mineral formula and Endmember calculations. Metamorphic stable mineral assemblages; Projections; Gibbs free energy; Phase rule, Metamorphic reactions; Mineral equilibrium; Influence of compositional variations. Geothermobarometry; Schreinemakers method; Petrogenetic grid; Phase diagrams; P-T-t paths, Thermochronology. Metamafics and Metaultramafics: Assemblages, Facies series; Metamorphism of felsic rocks; Metapelites: Barrovian sequence; Metacarbonates and metacalcareous rocks; Fluid inclusions; Metasomatism; Tectonic significance. High-pressure (HP) and High-temperature (HT), Ultra high-pressure (UHP), Ultra high-temperature (UHT) metamorphism: P-T ranges, textures, Mineral assemblages, Mineral chemistry and Tectonic setting. Metamorphism in plate boundaries; Collisional tectonics. Using petrological datasets; linking petrology with field information, structure, geochemistry and geochronology; Petrogenesis and tectonics interpretations. Case studies and examples on metamorphic evolution, P-T history; petrogenesis and tectonic setting of some global and Indian metamorphic terranes.

Applied Hydrogeology (ES666) [9 credit]

Course Content: Role of water in Earth's climate; Hydrological cycle and its components; Monitoring of hydrologic storages and fluxes; Water budget computations; Water-bearing properties of rocks - porosity, intrinsic permeability, specific yield and specific retention; Vertical distribution of sub-surface water; Classification of aquifers; quantitative assessment of aquifer properties; Aquifer parameters: transmissivity, hydraulic conductivity and storage coefficient; Determination of permeability in laboratory; Concept of heterogeneity and anisotropy; Characteristic differences between confined and unconfined aquifers; Hydrostatic pressure; Fluid potential; Energy in groundwater; Hydraulic head; Theory of groundwater flow; Darcy's law and its applications; Specific discharge; Limitations of Darcy's Law; Reynolds Number; Governing equation for flow through porous medium; Steady and non-steady state flow - Initial and boundary conditions; Solution of flow equations; Dupuit's Assumption; Boussinesq Equation; Groundwater flownet analysis; Groundwater flow patterns, Groundwater-Surface water interactions; Determination of flow direction. Flow through aquifers: 2-D groundwater flow equations; Flow under steady and non-steady state conditions; Evaluation of aquifer parameters of confined, semi-confined and unconfined aquifers - Thiem, Theis and Jacob methods.

Applied Sedimentology and Basin Analysis (ES653) [9 credit]

Course Content: Introduction to applied sedimentology, Siliciclastic, Carbonate, Phosphates, Iron-rich and Evaporite sediments and their economic significance; Physical properties of sediments – density, porosity and permeability, field and laboratory methods of their determination (rock physics properties); Sedimentary Basins- Basin-forming mechanisms; Basins due to lithospheric stretching, flexure and strike-slip; classification and evolution of sedimentary basins; Metallogeny, and Petroleum system in sedimentary basins; Major external controls on sedimentation; Continental sedimentary environments; Marine sedimentary environment; Basin fills and stratigraphy; Subsidence and Thermal history; Sediment to rock - the Subsurface Environment.

Aqueous Geochemistry (ES643) [9 credit]

Course Content: Course will primarily cover (1) the quantification of key geological processes controlling the chemical composition of water, precipitation and dissolution of certain minerals, and fluid–mineral interaction; (2) Chemical principles of weathering and its effects on water chemistry; (3) application of stable and radioisotopes to understand the source, pathways, and age of water; (4) contaminant geochemistry of some elements. Detailed topics to be discussed are: chemical thermodynamics and kinetics, aqueous complexation, acids and bases, redox geochemistry and Eh-pH-pE diagrams, carbonate geochemistry, chemical weathering, adsorption-desorption reactions, tracing of water cycle, controls on water chemistry, groundwater dating, and contaminant geochemistry.

Introduction to Profession & Communication Skills in Earth Sciences (ES600A) [3 credit]

Course Content: This course will fulfil the requirement of communicating more effectively at work and achieving your goals. Improving communications skills and becoming aware of the future pathways are essential to developing the most successful strategies and using them to advance career goals. You'll also learn how to present your work (written and oral) and, most importantly, what to do and what not to do.

Experimental Rock Mechanics & Rock Physics (ES657) [9 credit]

Course Content: Introduction and historical development; Principles and terminologies; Sensors, transducers and their calibrations; Design of deformation apparatus, safety features; Selection, preparation and dimension of samples; Uniaxial, biaxial, triaxial and torsion test set-up; Rock mechanics at room and high pressure temperature; Rate dependent rheology; Role of porosity, pore-fluid, grain size and mechanical anisotropy; Collection and processing of experimental data; Understanding stress-strain and related curves; Calculation of flow-laws, effective-viscosity and frictional properties; Mechanics of crystalline and porous rocks; Recovery and post-processing of deformed samples for further physical and chemical analysis; Measurement of electrical; thermal and hydraulic (liquid and gas) conductivity of rocks; Techniques of ultrasonic pulse transmission (V_p-V_s) and acoustic emission; Applications and limitations.

Geodynamics (ES667) [9 credit]

Course Content: The course is designed to understand the dynamics, flow of mass and energy of solid Earth in a quantitative manner. It contains Kinematics of Plate Tectonics - Earth's structure, hotspots and mantle plumes, convergent, divergent and transform plate boundaries, plate motion on flat and sphere Earth; Basics of Elasticity and Flexure – body and surface forces; stresses in 2D and 3D; isostasy, linear elasticity, uniaxial stress and strain, pure and simple shear, 2D bending or flexure of plates, application to Earth's lithosphere; Heat transfer - Fourier's Law of heat conduction, Earth's surface heat flux, 1D and 2D heat conduction with advection, basics of thermochronology, frictional heating on Faults; Fluid mechanics - 1D channel flow, pipe flow, Asthenospheric Counterflow, mantle convection, diffusion of groundwater; Faulting - classification of faults, friction on faults, Anderson theory of faulting, thrust sheets and gravity sliding, earthquakes.

Geophysical Methods (ES656) [9 credit]

Course Content: Introduction to different geophysical methods; Concepts of gravity and magnetism, working principles of measuring instruments, field operations, micro-gravity survey, gravity and magnetic gradiometry, data reductions, regional-residual separation, direct and indirect interpretation and applications; Elementary theories of DC resistivity, resistivity surveying equipment's and different arrays, interpretation of electrical sounding and profiling data, IP measurements in time and frequency domains, applications of SP methods; EM induction theory, time and frequency domain EM, EM systems for ground, marine and airborne surveys, working principles of VLF, MT and GPR and their applications; Theory of elasticity and wave propagation, concept of rays, ray paths in layered media, principles of marine and land seismic sources and receivers, land and marine seismic data acquisition techniques, data pre-processing - static corrections, multiple attenuation techniques, filtering and processing steps – NMO, velocity analysis, stacking, migration, interpretation of migrated sections, basics of Tomography and AVO; Principles of well logging, Archie's law, different petro-physical parameters, different logging techniques and interpretation of field log data.

Geology and Geochemistry of Petroleum (ES647) [9 credit]

Course Content: History of petroleum and gas exploration in India; Carbon cycle, origin and preservation of organic matter-*the source material of petroleum;* Oil and gas bearing rocks, reservoir rocks, trap and seal rocks-*the petroleum system key components;* Petroleum generation, migration, and accumulation- *the petroleum system processes;* Composition of crude oil and oilfield water – *upstream and downstream linkages;* Multiple controls on petroleum biodegradation and impact on oil quality; Classification of oil and gas accumulations; Geochemical screening of source rocks and petroleum - total organic carbon, petrographic analysis of macerals, vitrinite reflectance, elemental analysis of kerogen, rock eval pyrolysis, thermal alteration index, organic biomarkers, trace metals, carbon isotopes, and radiogenic isotopes; Application of geochemical tracers in petroleum exploration. Age of oil deposits, oil-oil correlation and oil-source correlation techniques, reservoir Compartmentalization issues, identification of oil-bearing horizons and reservoir rocks from geochemical logs, and reservoir filling history; Unconventional oil and gas resources. Oil shales, tar sands, and gas hydrates; Petroliferous basins of India. Case studies on specific oil producing Indian basins; Petroleum and environment; future of hydrocarbon resources.

Instrumentation in Earth Sciences (ES648) [9 credit]

Course Content: Near subsurface mapping using Ground Penetrating Radar (GPR) – mapping of buried structures, depth determination of underground bodies and lithounits; Generation of Digital Elevation Models (DEM); Landform mapping using Total Station, Integrated TS-GPS system and by Real Time Kinematic (RTK) survey; Field training including geological mapping; X-Ray Diffraction – sample preparation and interpretation of XRD charts for qualitative and semi-quantitative analysis of crystalline materials; Principles and theory of Scanning Electron Microscopy (SEM); Sample preparation, coating, imaging and analysis; X-Ray Fluorescence – sample preparation and semi quantitative and quantitative chemical analysis of geological samples; sample-acid digestion and chemical analysis by Inductively Coupled Plasma Mass Spectrometry (ICP-MS).

Isotope Geochemistry and Applications (ES649) [9 credit]

Course Content: Nucleosynthetic processes and the isotopic abundances of elements, Decay mechanisms of radioactive atoms, Equations of Radioactive Decay and Radiogenic Growth, Geochronology using radioactive decay schemes of Rb-Sr, Sm-Nd, U-Th-Pb, K-Ar, U-series disequilibrium method of dating, 14C dating, Fission track Dating, Analytical methods in Thermal Ionization Mass Spectrometry, Isotope Geochemistry of the Earth's Mantle and crust, Isotopic evidence regarding the formation of the Earth, Stable Isotope Theory, Kinetic and equilibrium isotope fractionation, Analytical methods in Stable isotope ratio mass spectrometry, Specific applications of stable isotopes in hydrology, climate and environment, archaeology and paleontology, Carbon cycle and climate.

Mathematics for Earth Sciences (ES651) [9 credit]

Course Content: Introduction to importance of mathematics in Earth sciences, Basics of MATLAB; Vector analysis, Grad, Div, Curl, application of Gauss's Theorem to potential methods and seismology; Matrix analysis, Matrix inversion for the solution of simultaneous equations; Coordinate systems: Curvilinear coordinates, Cartesian, Cylindrical, and Spherical coordinates, Applications of coordinate systems to Plate motion, (non) seismic; Complex analysis in geosciences; Tensor analysis and its application to (non) seismic and geodynamics; Ordinary and partial differential equations, separation of variable, numerical solution to Heat diffusion equation; different data types in Earth sciences, methods of data analysis: Univariate Statistics, Empirical distributions, theoretical distributions, statistical tests (χ^2, Kolmogorov-Smirnov and Kuiper tests), Bivariate and multivariate Statistics, Correlation coefficient, linear regression analysis, bootstrap estimates, Data modeling, best fit, fitness evaluation; Multiple correlation coefficients; basics of geophysical signal processing.

Mineral Resource Exploration (ES671) [9 credit]

Course Content: Introduction to mineral exploration; stages of mineral exploration, crustal abundance and geochemical behavior of the elements; geochemical anomalies; geochemical cycle: primary dispersion, secondary dispersion; pathfinder/indicator elements; geodynamic settings of mineral deposit systems; different types of ore deposits and their metallogeny**,** surface and subsurface mineral exploration methods, analytical techniques in mineral exploration, ore reserve estimation, national mineral policy, Indian mineral Deposits, prospecting techniques for base and strategic metals.

Natural Hazards (ES658) [9 credit]

Course Details: Natural Hazards and Disasters, Human Impact on Natural Disaster, Predicting Catastrophe (*01*), Mitigating Hazards; Plate Tectonics and related Hazards; Earthquakes and their causes, Ground Motion and Failures; Tsunami: Giant Tsunamis, Generation and movement, Tsunami Hazard Assessment; Volcanic Eruption and Hazard: Eruption-Type of Volcanoes and Tectonic environment; Landslide and other downslope movements: Causes of Landslides, Type of downslope movement, associated hazard; Land Subsidence and associated hazard; Floods and Human Interaction, Flood Frequency and Recurrence Interval; Human intervention and mitigation; Storms: Tropical Cyclone, Hurricane, Tornado, Storm damage and safety; Wildfires: Fire Process and Secondary effects.

Non-traditional Stable Isotope Geochemistry (ES663) [9 credit]

Course Content: Notation for stable isotope systems, reference standards, equilibrium and kinetic fractionations of non-traditional stable isotopes, history of non-traditional stable isotope-based research, method of sample preparation (e.g., ion exchange chromatography), measurement techniques (in-situ and non-in-situ) by mass spectrometry, data correction (e.g., sample-standard bracketing, internal normalization, double spike etc.) and representation, applications of stable Ca, Mg, Li, K and Zn isotope systems in low and high T systems including isotopic fractionation during continental weathering, surface runoff, nutrient transfer from root to leaf of vegetation etc.; coupling of continental and oceanic processes, inter-mineral isotopic fractionation and bond-lengths, bulk-silicate Earth compositions, diffusion in silicate melts, isotopic compositions igneous rocks formed at different tectonic settings, isotopic compositions of Lunar and Martian rocks, isotopic fractionation during nucleosynthesis and early volatile depletion process, isotope transport model from food to blood, between soft tissues, bone loss or bone cancer.

PG Seminar in Earth Sciences (ES702) [0 credit]

Course Content: The course would have the dual purpose of: a) familiarizing the PG students with their colleagues' current themes and progress. b) In the process PG students would learn best practices in oral presentation and preparation for talks. Both these objectives need sustained exposure over many semesters, and it needs to be a weekly habit of attending such sessions.

Physics of Earthquakes (ES665) [9 credit]

Course Content: Elastic rebound theory, earthquake and its mechanism, tectonic plate motion, earthquake characteristics, earthquake source parameters, seismic moment and magnitude, seismic intensity, seismic wave types and properties, faulting in nature, types of fault setting, fault asperities, seismic cycle and a wide range of fault slip behaviors (stable creep, slow slip, regular earthquakes, supershear ruptures and more), frictional laws, concepts of static and kinetic friction, Amonton's law, Byerlee's law, stick-slip and stability of frictional sliding, velocity-jump experiments, Rate- and State-dependent friction law and parameters, elastodynamic parameters, loading conditions, velocity-weakening and velocity-strengthening properties, stability condition, earthquake cycle modeling, modeling methods, spring-slider model, finite-fault modeling, model parameters and applications, estimating static and dynamic stress drop, slip, and recurrence interval, a multi-disciplinary approach involving seismological observations, laboratory friction experiments, and numerical modeling, case studies of observations and modeling of stable creep, slow slip and tremors, bilateral and unilateral ruptures, repeating earthquakes, supershear ruptures, etc.

Planetary Geomorphology: Processes and Landforms (ES683) [11 credit]

Course Content: This course will introduce the workings of various surface geological processes on planetary bodies other than Earth. The course would cover a diverse array of landscapes carved out by geological processes in substrates made up of various compositional species. The course aims at broadening the

Perspective on how a geological process operates, what are its various facets and how they interact with the substrate to produce a landscape. The course would therefore equip the students to infer geologic history of a region based on the study of its landscape. The course would comprise a combination of lectures and labs.

Potential Field Theory in Applied Geophysics (ES681) [9 credit]

Course Content: This course will provide comprehensive background about the concept of potential field theory, related mathematical tools, and its application in geophysics. It will help to develop the concepts of various data processing and interpretation approaches related to potential field methods (e.g., Gravity and magnetic methods). The major topics of this course are: Introduction to potential field theory: fields and potential, Poisson's & Laplace's equations, Helmholtz theorem, Delta & Green's functions, Green's identities.
Fourier series and Fourier transform in spatial domain: power spectra analysis; Solution to Laplace's equation in cartesian & spherical co-ordinates: upward and downward continuation, spherical harmonics, Geoid & ellipsoid, and geomagnetic field representation; Gravity and magnetic methods of prospecting: instruments, data processing/enhancement, and interpretation.

Remote Sensing and GIS for Geo-resource Evaluation (ES644) [9 credit]

Course Content: Remote sensing platforms – satellite-based and airborne sensors; Basic principles of image interpretation; Spectra of earth's surface material; Interpretation of regional geological and geomorphological features; Lithological and structural mapping, mapping of landforms and interpretation; Basic principles of Geographic Information System (GIS) and its application; Analytical Hierarchy Process (AHP) technique and its integration into GIS. River basin management – drainage mapping, channel movement and morphological changes; river erosion studies; Identification of groundwater potential zones; criteria for identification, integration of controlling factors into GIS; Lake and wetland studies using remote sensing; Water quality mapping; water quality parameters, indices of water quality monitoring; Vegetation Mapping and forestry applications; Application in glaciology and snow hydrology; Coastal zone mapping and other related applications; Natural hazards – floods, landslides, earthquakes; causative factors, choice of data and use of remote sensing technique for mapping and prediction; Mineral resources evaluation with particular reference to digital remote sensing; Application of thermal infrared data for mapping surface moisture and rock types and environmental studies.

River Science (ES645) [9 credit]

Course Content: Integrated Multi-Disciplinary Approach in river science; River Science in Indian Context; Geomorphic Analysis of River Systems - Key Concepts in River Geomorphology, Catchment Scale Controls on

River Morphology, Catchment Hydrology, Sediment Movement and Deposition in River System, Channel Geometry, Floodplain Forms and Processes, River Diversity and River Evolution, Human Impacts on River Systems; River Ecosystem Synthesis - Introduction to hydrogeomorphic patches, functional process zones, hierarchical patch dynamics and biocomplexity, river as a continuum, longitudinal, lateral, temporal, vertical dimensions; Hierarchical patch dynamics in riverine landscapes; hydrogeomorphic character of a riverine ecosystem.; Ecological Implications of RES Biocomplexity Concepts; River Health and River Futures - Human impacts on river systems including climate change impacts; river hazards and their causes, Environmental Flow (e-flow) – definition, data requirement, different approaches for e-flow estimation; Integrated approach to river management, River health and river futures.

Rock Magnetism (ES664) [9 credit]

Course Content: Rock magnetism is an umbrella term that covers the study and application of magnetism and magnetic fields of natural crystals, minerals and rocks, which have formed and deformed at various pressures and temperatures. The five broad titles and the topics covered therein are as follow: (1) Introduction: Introduction to magnetism. Types of magnetism. Magnetic fields in the Solar system. (2) Magnetic mineralogy: Ferro-, para- and diamagnetic minerals; hysteresis, coercivity and magnetic domains; sampling, measurement and analysis. (3) Magnetic anisotropy: Types of anisotropies of magnetic susceptibilities (AMS); AMS parameters and ellipsoid; primary magnetic fabrics; secondary magnetic fabrics; sampling, measurement and analysis. (4) Geomagnetism: Earth's magnetic field origin, present and past; Induced and remnant magnetization; Sampling, measurement and analysis. (5) Applications: AMS, tectonic deformation and strain; magnetic shock barometers; magnetic anomalies on extraterrestrial crust; seafloor spreading and paleogeographical reconstruction; paleomagnetism and tectonics; lava emplacement conditions; Bio-, environmental-, archeo-magnetism; Rock magnetics in mining, petroleum and geothermal industry.

Solid Earth Geophysics (ES655) [11 credit]

Course Contents: This course will introduce the laws of physics in understanding the Earth Structures and geological processes associated with the Earth. It will focus on the application of basic mathematics and physical concepts to better understand the structure and composition of the Earth's interior and interaction among crust, mantle, and core. It will provide qualitative as well as quantitative knowledge on Earth structures and plate tectonics using Earth’s gravity-magnetic fields, seismic reflection and refraction, seismology and thermal processes.

Seismic Exploration & Subsurface Imaging (ES682) [9 credit]

Course Content: Acoustic and elastic wave equation, energy partitioning at interface, AVO analysis, Fourier analysis and seismic signals, signal processing, reciprocity and Green's function, land and marine seismic data acquisition techniques, wavefield sampling, wavefield, decomposition, land and marine seismic data processing (filtering, deconvolution, CMP, CDP, stack, migration), advanced migration techniques (RTM, PreSDM), seismic inversion, optimization techniques, tomography, finite difference scheme for 2D/3D seismic modeling, Ambient noise tomography, land and marine seismic interpretation

Quaternary Geology and Tectonic Geomorphology (ES680) [9 credit]

Course Content: Quaternary time scale; Quaternary stratigraphy and geochronology – dating Quaternary records, radiometric, luminescence and other methods of dating. Climate archives and proxies, Methods of reconstructing Quaternary climate - sedimentary archives, biotic proxies, geological and geochemical proxies. Sea level changes, glacial/interglacial cycles, sea floor spreading, carbon reservoir, vegetation dynamics, migration history, response of vegetation to climatic reversals. Tectonic geomorphology and landforms:

mapping active tectonic landforms, geomorphic markers and indices; Tectonics-climate coupling, BLAG hypothesis, Uplift-weathering hypothesis.