Indian Institute of Geomagnetism (IIG) is an autonomous research institute under Department of Science and Technology with its Headquarters at New Panvel. It operates three regional centres, namely, Dr. K.S. Krishnan Geomagnetic Research Laboratory (KSKGRL), Prayagraj, Equatorial Geophysical Research Laboratory (EGRL), Tirunelveli and North-East Geophysical Research Laboratory (NEGRL), Shillong, with 12 magnetic observatories nationwide to monitor the geomagnetic field. IIG is a premier institute conducting basic and applied research in Geomagnetism and allied fields like Solid Earth Geomagnetism/Geophysics, Space and Atmospheric Sciences that covers several phenomena from surface of the Sun to the interior of Earth. Recently, the research activities are extended to Planetary Ionosphere-Magnetosphere systems as well. In 2022, IIG achieved a milestone of completion of 50 years of its existence as an autonomous organization under Government of India. It hosts the world famous Colaba-Alibag magnetic observatory that has heritage of over 180 years of continuous geomagnetic observations. IIG supports a World Data Centre for Geomagnetism, which is the only International Centre for geomagnetic data in South Asia to cater to the need of scientists in this region. The Instrumentation team of IIG has expertise in the development of the ground magnetometers. IIG has a global presence by virtue of which its scientists are involved in collaborations with scientists from other countries to strengthen their research.

Place of Research Work: The selected candidate will have to carry out his/her research work either at IIG Headquarters in Navi Mumbai or any of the regional centres (EGRL-Tirunelveli /KSKGRL-Prayagraj/ NEGRL-Shillong) of IIG.

Application Procedure

The soft copy of application form is available on http://www.iigm.res.in/careers/research-scholars. Duly filled application form, along with self-attested copies of the academic (SSC onwards) and other certificates shall reach IIG by the mode (soft copy or hard copy) as stated in the advertisement. After completion of the application process, the candidate is required to take a print out of the form and produce it for document verification at the time of interview.

Course work, Tenure, extension, accommodation and leave for Research Scholar

1. All Research Scholars must undergo course work offered in two semesters. The course work syllabus will be as per the UGC guidelines consisting of core courses and advanced level courses (offered as electives). The electives include advanced level courses, which will prepare the students for their Ph.D. degree. The core courses are mandatory and electives can be decided in consultation with the respective supervisors. Examination of the respective courses will be conducted at the end of each semester. The Research Scholar

has to obtain a minimum of 55% marks in aggregate in each semester of the course work in order to be eligible to continue in the programme. The students will be given only two attempts to clear their course work examination, failing which they will not be able to continue with the Ph.D. program. Minimum 80% attendance is mandatory during the course work.

2. The tenure of fellowship to Research Scholars is five (05) years and they should submit their Ph.D. thesis within this time frame. The research fellowship will not be admissible beyond five years tenure. However, hostel facility may be provided for extended stay subject to availability and on applicable payment basis as per IIG norms.
3. Under extraordinary circumstances, Research Scholars may be permitted access to facilities like Library, labs, computers etc. during the extension period, if it is sanctioned, and following due office procedure.
4. Students shall be paid a book grant of Rs. 10000/- per annum for a maximum period of three years starting from second year onwards. The year is counted from the date of their joining the Institute. The book grant cannot be used for any other purpose. Advance payment of book grant is not allowed. All books should be purchased through library. The Research Scholars who have utilized the book grant will be advised to return the books to the institute at the end of their tenure and before leaving the Institute. This will be applicable to the batch of students who have joined during the academic year 2022-2023 and later.
5. In addition, during their tenure period of 5 years, Ph.D. registration fees/annual Ph.D. university fees/thesis submission fees/synopsis fees/printing/binding charges related to thesis and any other fee/charges levied by the university where the student registers for Ph.D., will be reimbursed to the students. Beyond the 5-year tenure, reimbursement of these charges will be considered only in exceptional cases. All other expenses such as those related to registration in domestic / foreign conference/workshop (as applicable), abstract submission fees, stationeries, external hard disks, etc. shall be borne by the Institute through respective projects of Ph.D. Guide.
6. Application for extension of Ph.D. tenure beyond the 5-year term (see Annexure–I) must be forwarded through their supervisors one month prior to the end of the students' tenure. Late applications will not be processed. Such applications are allowed only two times and the possible extension period is maximum of up to one year (two semesters) only. Fellowships will not be provided to students on such extensions beyond the regular five-year tenure.
7. Students visiting outside the campus for their personal work (other than university matters and Ph.D. related work) should apply for leave. The attendance should be regularized (in regularization slip recommended by student's guide) for their absence while visiting the university in connection with their Ph.D. related works.

8. The fellowship form of the research scholar to be signed by the supervisor every month, in addition to the attendance sheet.

Annual progress review, Ph.D. registration, Ph.D. submission for Research Scholar

1. For all Research Scholars, annual review will be conducted for their fellowship extension every year before the completion of their academic year (the first academic year is reckoned to commence from the date of their joining the Institute). However, their "research work progress" will be reviewed every six months by Academic Program Committee (APC). During their 2nd and 4th year, corresponding supervisors (internal & external) will also be part of the annual review committee in addition to APC members.
2. All Research Scholars should submit their annual progress report to APC every year, well before the review date.
3. Research Scholars are encouraged to give frequent formal/informal seminars/discussions in academic meetings guided by APC based on literature survey or any new finding relevant to IIG's activities. Also, every student shall give a synopsis talk at IIG before his/her thesis submission.
4. Research scholars should complete their Ph.D. registration process by the end of second year of their tenure to avoid delay in the submission of their Ph.D. thesis. In this context they are advised to qualify NET/PET/GATE examination as required by the respective Universities (where student wants to enrol for Ph.D. degree), if not qualified earlier, during the first year of their tenure.
5. Research scholars shall inform APC as soon as they register for their Ph.D. in a university. The same will be followed when they submit Ph.D. thesis to their respective university. Once awarded, they should provide a copy of their degree for office records. The students should submit a soft/hard copy of their thesis to library.
6. Submission of plagiarism report and no dues (for all concerned sections) is mandatory before thesis submission.
7. While fixing date of Ph.D. Voce-Viva email copy should be marked to Director and APC chairperson and necessary approvals to be obtained. Their availability should be considered while fixing the date
8. All research scholars should mandatorily be included under a medical insurance scheme as per IIG's existing norms and this procedure should be done by IIG, HRD.

Participation in national and international conferences/workshops/schools for Research Scholar

1. Participation in International conferences/symposia/workshops (relevant to their topic of research) will be allowed based on the recommendations of APC and at the discretion of Director. Preference will be given to those who get partial financial support from outside and those who have not attended any conference previously with IIG financial support.
2. Participation of Research Scholars in conferences/workshops/symposia/training schools, where full financial support is received from other Indian/foreign agencies/organizations will be encouraged.
3. International conferences hosted in India are treated as national conferences.
4. Research scholars are encouraged to apply for international/national schools/workshops/trainings during their first three years of Ph.D. tenure and for paper presentations in meetings/symposia/conferences during the fourth and fifth years of their Ph.D. tenure.
5. Prior permission should be obtained before applying to national and international conferences/workshops/symposia/schools/training programs (See Annexure V). In addition, the usual procedure of taking prior approval for the submission of abstract and payment of abstract submission fee would apply to Research Scholars as well (the format for the Abstract Display cum In-Principle Approval Form for Article Publication Charges is attached as Annexure-II).
6. During Ph.D. tenure, students who are applying for short-term international visit via various fellowships/exchange program etc. are required to take prior approval from Director before applying for the same (See Annexure V). Their requests are to be necessarily routed through APC with recommendation of their Ph.D. guide. Research Scholars should abstain from applying for fellowship during the fifth year of their Ph.D. tenure as their focus during this period should be on completing their thesis work. In any case such foreign visits total period shall be maximum up to ninety days in entire five-year tenure of Ph.D.

Ph.D. COURSE-WORK SYLLABUS

(September 2022-continuous)

Research Areas/Subjects

1. Geophysics,
2. Applied Geology,
3. Atmosphere & Climate Science
4. Environmental sciences
5. Physics (Space Physics)

Over All Course Co-ordinator

1. Prof. Gurubaran
2. Prof.Bharati Kakad

Course Code	**Name and Nature of Course**	**Credits [1credit=15 lectures]**
SMESTER - I		
Core Courses		
CC-001	Research Methodology -1	2
CC-002	Research Methodology -2	2
CC-003	Research Methodology -3	2
Total		6
Electives (Semester-I) (Students to opt any **two** elective papers)		
EL-001	Electrodynamics	2
EL-002	Basics of Geomagnetism	2
EL-003	Basics of Atmospheric physics and chemistry	2

EL-004	Introduction to Applied Geology	2
EL-005	Physics of the Earth	2
EL-006	Measurement techniques in applied geomagnetism research	2
Total		4
Electives (Semester-II) (Students to opt any **three** elective papers)		
RT-001	Plasma Physics	2
RT-002	Ionospheric Physics	2
RT-003	Magnetospheric Physics	2
RT-004	Mathematical Physics	2
RT-005	Geopotential Methods	2
RT-006	Electrical and Electromagnetic Methods	2
RT-007	Introduction to Weather and Atmospheric processes	2
RT-008	Climate Dynamics and Modelling	2
RT-009	Paleomagnetism, Archeomagnetism & Environmental Magnetism	2
RT-010	Earthquake and Lithosphere-Atmosphere-Ionosphere Coupling, Ionospheric Seismology, Paleoseismology	2
RT-011	Geologic and Tectonic Framework	2
Total		**6**

Syllabus (Ph.D. COURSE WORK)

Semester I

CC-001: RESEARCH METHODOLOGY – 1

Numerical Methods and Programming [10h]*:* Introduction, solution of nonlinear equations, solution of linear systems, interpolation, curve fitting, numerical differentiation, numerical integration, solution of differential equations, numerical schemes and its implementation in simulation codes, numerical analysis using Runge–Kutta methods.

Training on Computer Programming [10h]: Introduction, 2-d/3-d plotting, graphical interface, basic data analysis / signal processing using Matlab, programming in Matlab, basics of FORTRAN and C.

Basic Statistics, Signal Processing Methods and Techniques [10h]: Introduction to qualitative and quantitative analysis. Difference between quantitative and qualitative analysis methods. Standard deviation, variance, skewness, kurtosis, transforming data, probability distributions, confidence interval, hypothesis testing, correlation and regression, least square method, error, error estimates, standard errors. Introduction to Digital Signal Processing (DSP), Digital Filtering: concepts and usage, processing in time and frequency domain, numerical filters, Fourier transforms, spectra, spectrograms, convolution, deconvolution.

References

1. Fast Fourier transform by Brigham
2. Fundamentals of Statistics by Dasgupta
3. Introduction to statistical signal processing by R. Gray
4. The Mathematica Book, Fifth Edition by Stephen Wolfram
5. A Guide to MATLAB for Beginners and Experienced Users by Hunt et al., Cambridge (freely available)
6. MATLAB Recipes for Earth Sciences by Martin H. Trauth
7. Statistics by M. R. Spiegel and L. J. Stephen
8. Statistical Methods by G. Snedecor and W. Cochran

CC-002: RESEARCH METHODOLOGY – 2

Fundamentals of research and field survey [10h]: Philosophy and hypothesis of research, types of hypothesis, methods of testing hypothesis. Various types of research methods – descriptive, analytical, fundamental, applied, qualitative, quantitative, conceptual, empirical, surveys, fields, correlations, experimental and quasi-experimental ex-post facto research, critical and action-oriented research, biographical, phenomenological. Travel plan, logistics, check lists, seasonal

clothing, sampling gazettes, safety gazettes, first aid, handy eatables, tracking kit, log book, camera, sample preservation tools, portable equipment**.**

Data collection and field work [10h]: Field survey safety measures, post-field precautions, reporting preparation, data download, sample storage, analysis records.
Laboratory experiments, instrument calibration, data collection through instruments, sampling types, sampling protocols, sample preservation and transport, collection of different environmental samples, geological and geophysical samples preparation, Survey method-field surveys, preparation of questionnaire, interview etc. Other miscellaneous methods- from online publications, library search, archives etc. hands on sessions with instruments.

Literature Survey and Manuscript Preparation [10h]: Scientific approach for literature survey for historical background of research. Scrutiny of available data sets, qualitative analysis of information and finalizing research problem. Structuring the article-title, authors, affiliations, contact details, abstract, Introduction, methodology, statistical analysis, results and discussion, interpretation of results. Preparation of tables, drawing figures, conclusion, acknowledgement, referencing etc. Communication needs before submission of manuscript- manuscript file, author details, reviewer's names, key words, abstract, graphical abstract, funding information, declaration of conflict of interests, cover letter, highlights, Significance of academic meetings/webinars, difference between seminars/workshops/conferences terms.

References:

1. Research Methodology, Peter Pruzan
2. Coen Louis, Lawrence Manion and Keith Morrison. 2011. Research Methods in Education. Seventh ed. Routledge Taylor, London.
3. Creswell, J W. 2014. Research Design: Quantitative and Mixed Methods Approaches. Fourth ed. Sage Publication.
4. Donohue J C. 1990. Understanding Scientific Literature: A Bibliometric Approach. MIT press, London.
5. Egghe L., and Rousseau R. 1990. Introduction to Informatics: Quantitative Methods in Library, Documentation and Information Science. Elsevier, Amsterdam.
6. Data Collection and Management: A Practical Guide by M. Loeber and W. Kammen
7. Panneerselvam R, 2004. Research Methodology, Prentice Hall of India, New Delhi
8. Kothari, C.R.,1985, *Research Methodology-Methods and Techniques,* New Delhi, Wiley Eastern Limited.

CC-003: RESEARCH METHODOLOGY 3

Research Problem Formulation [10h]: Research definition, objective of research, literature review, identification of research gaps, defining or selection or identification of a research topic or problem, developing the objectives, cross-disciplinary thoughts and inter-disciplinary research approaches of addressing the question, preparing the research design including sample design, sample size. Data collection methods - observations, field, survey, website etc. Generalization

and interpretation of analysis, preparation of the report on conclusions reached, testing validity of research outcomes, suggestions and recommendations, identifying future scope.

Philosophy and Ethics [10h]: *In*troduction of Philosophy: definition, nature and scope, concept, branches. Ethics: definition, moral philosophy, nature of moral judgments and reactions. Scientific conduct - ethics with respect to science and research, intellectual honestly and research integrity, essential qualities of a researcher – scientific temperament and attitude, scientific misconducts: falsification, fabrication and Plagiarism, reductant publications: duplicate and overlapping publications, salami slicing, Selective reporting and misrepresentation of data.

Publication Ethics [10h]: Publication ethics: definition, introduction and importance. Best practices/standards setting initiatives and guidelines: COPE, WAME etc. Conflicts of interest. Publication misconduct: Definition, concept, problems that lead to unethical behaviors and vice versa, types. Violation of publication ethics, authorship and contributorship, Identification of publication misconduct, complaints and appeals. Predatory publishers and journals. Publication Misconduct: Ground Discussions, Subject specific ethical issues, FFP, authorship, Conflict of interest, Complaints and appeals: examples and fraud from India and abroad, software tools- Use of plagiarism software. Open access publications and initiatives, SHERPA/RoMEO online resource to check publisher copyright and self-archiving policies. Information about publishers like Elsevier, Springer Journal etc.

References:

1. Bird, A. (2006). Philosophy of Science. Routledge. pp 324.
2. Singhvi, A.K. (2019). Ethics in Science Education, Research and Governance. Indian National Science Academy, New Delhi
3. Chaddah, P (2018). Ethics in Competitive Research. Self-Published. pp 128
4. Shamoo, A.E. and Resnik, D.B., Responsible Conduct of Research, 2003
5. Todorovich, M., Kurtz, P., Hook. The Ethics of Teaching and Scientific Research. 1977

Electives

EL-001: ELECTRODYNAMICS

Electrostatics [5h]: Coulomb's law, electric field for continuous and discrete charge distribution, Gauss's law, (Integral and differential form), scalar potential, potential energy of charge in the electrostatic field, Surface distribution of charges and dipoles, Discontinuities in the electric field and potential, Poisson and Laplace equations, Dirichlet and Neumann boundary conditions, multipole expansion of the potential and multipole moments, Electric field at a point due to an electric dipole.

Magnetostatics [5h] : Concept of magnetostatics from continuity equation, Biot-Savart law, Forces between two current-carrying loops, differential equations of magnetostatics and Ampere's law, Vector potential, magnetic fields of a localized current distribution, magnetic moments, Faraday laws of induction.

Maxwell Equations, Conservation laws *[10h]*: Maxwell's displacement current, Maxwell equations, electric field in terms of vector and scalar potential, wave equations, Gauge transformations(Lorentz and Coulomb gauge), Green function for the wave equation, advanced and retarded solution and causality, Poynting theorem and conservation of energy and momentum for a system of charged particles and electromagnetic fields.

Plane electromagnetic waves and wave propagation [10h]: Plane wave in a non-conducting medium, linear and circular polarization, stokes parameters, reflection and refraction of electromagnetic waves at a plane interface between dielectrics, Frequency dispersion characteristics of dielectrics, conductors and plasmas, concept of group velocity and phase velocity.

References

1. W. Greiner, Classical Electrodynamics (Springer- Verlag) 2000.
2. M.A. Heald and J.B. Marion, Classical Electromagnetic Radiation, 3rd edition (Saunders, 1983)
3. J.D. Jackson, Classical Electrodynamics, 4Th edition, (John Wiley & sons) 2005
4. W.K.H. Panofsky and M. Phillips, Classical Electricity and Magnetism, 2nd edition, 1962.
5. D.J. Griffiths, Introduction to Electrodynamics, 1989.

EL-002: BASICS OF GEOMAGNETISM

Introduction to Geomagnetism [10h]: **Geodynamo-**origin and sources of geomagnetic field, geomagnetic field elements, different periodicities and their implications, field variation of

external origin, solar quiet variations, disturbed time variations, geographic and geomagnetic coordinates, concept of universal time, local time and magnetic local time.

Geomagnetic field models [10h]: Introduction, geomagnetic field modelling, magnetic field models (IGRF, WMM), development of geomagnetic field models, its applications, model accuracy and errors, Hands on practice with geomagnetic field model data and its comparison with observatory data.

Geomagnetic activity identification [5h]: Geomagnetic activity indices, Dst, AE, AL, AU, SYM-H, ASYMH indices, Geomagnetic data, data processing, usage of observatory data, IIG's world data center importance of geomagnetic observatories.

Geomagnetic pulsations [5h]: Geomagnetic pulsations, source for pulsations, Magnetic field generated by ocean currents, planetary magnetic fields, and geomagnetic hazards.

References

1. Introduction to geomagnetic field by W. Campbell
2. Geomagnetism Volume I and Volume II by Chapman
3. Geomagnetism Volume I and II by J. Jacob
4. Magnetic observatory manual by H. E. McComb

EL-003: BASICS OF ATMOSPHERIC PHYSICS AND CHEMISTRY

Thermal structure and energy balance [6h]: Thermal equilibrium and the concept of radiative equilibrium temperature, simple laws, concept of scale height, concept of potential temperature, static stability

Radiative processes [6h]: Interaction of solar radiation with atmospheric gases, radiative transfer problem, thermal and photochemical effects of radiation

Atmospheric Motions [6h]: Laws of motion and the concept of vorticity, geostrophic approximation, thermal wind equation, Vorticity equation and Ertel potential vorticity

Waves in the Atmosphere [6h]*:* Shallow water approximation, orographic waves, internal gravity waves, Rossby waves, Equatorial waves, wave effects in the middle atmosphere.

Composition and Chemistry [6h]*:* Photochemical reactions, Oxygen chemistry, minor gases, Ozone distribution and chemistry, anthropogenic emissions and atmospheric responses, transport of chemically active species, chemistry and climate.

References

1. Atmospheric sciences, J. Wallace
2. Physics and chemistry of upper atmosphere, by M. Rees
3. Atmospheric Thermodynamics by Gerald R. North and Tatiana Erukhimova

EL-004: INTRODUCTION TO APPLIED GEOLOGY

Introduction to Geology [10h]: Concept of Geology and its scope, Earth and solar system: origin, size, shape, mass, density and its atmosphere. A brief account of various theories regarding the origin and age of the Earth. Introduction to Plate Tectonics. Brief idea of interior of earth and its composition. Basic idea of - Stratigraphy, Igneous, Metamorphic & Sedimentary Petrology.

Structural Geology [10h]: Introduction, Elementary idea of types of deformation; contours, topographic and geological maps; Elementary idea of bed, dip and strike Folds: nomenclature and types of folds. Faults: nomenclature, geometrical and genetic classifications, normal, thrust and slip faults. Definition, kinds and significance of joints and unconformity**.**

Hydrology and ground water [10h]: Definition of hydrogeology, Hydrological cycle. Hydrological parameters–Precipitation, evaporation, transpiration and infiltration. Origin of ground water-vertical distribution of ground water. Types of aquifers; water bearing properties of rocks - porosity and permeability; specific yield, specific retention.

Reference

1. Principles of Physical Geology 3rd Edition, Holmes A., 2016, Wiley
2. Understanding Earth 4th Edition, Frank Press & Raymond Siever, 2003, W. H. Freeman
3. Fundamentals of Structural Geology: Pollard & Fletcher
4. Fundamentals of Structural Geology 3rd Edition, R. G. Park, 2013, Routledge
5. Text Book of Geology: P.K. Mukherjee
6. Fundamentals of Hydrogeology, Akhauri, S and Akhauri,H.M.
7. Fundamentals of Hydrology 2nd Edition – T.Davie

EL-005: PHYSICS OF THE EARTH

Earth Structures [10h]: Formation, and evolution of earth, structure of Earth, Internal structure of the earth, composition of the earth. Distribution of elements, Earth composition from core to lithosphere. Structure and formation of oceanic and continental crust, Earth's magnetic field and paleomagnetism, Earth's shape and gravity field, the geoid, isostasy. Earthquakes. Variation of physical properties and seismic wave velocities inside the earth.

Earth's radioactivity and thermal properties [10h]: Radiation, radioactivity, half-life, decay constant, measurement techniques, dating methods and radioactive isotopes, Heat flow in continental and oceanic plates. Convection in the Earth's mantle and core.

Various Geophysical Exploration Methods [10h*].*

Reference

1. Applied Geophysics, Telford et al.
2. The Solid Earth by Fowler
3. Introduction to Seismology by Peter Shearer
4. Planet Earth by Press and Siever
5. Physics and Geology, by Jacobs and Russell
6. Physics of the Earth, by Stacey
7. The interior of the earth, by M.H.P. Bott
8. Heat Flow: Guide to Measurement and Modelling

EL-006: MEASUREMENT TECHNIQUES IN APPLIED GEOMAGNETISM RESEARCH

Instruments and working principals [15h]: Introduction to different instruments and their principals like Digital fluxgate magnetometer (DFM), Proton precession magnetometer (PPM), Induction coil magnetometer (ICM), and Declination inclination magnetometer (DIM), calibration of magnetometer. Magneto-telluric (MT), Susceptibility meter, vibrating sample magnetometer (VSM), Spinner magnetometer, demagnetizers, Resistivity meter, Global positioning system (GPS).

Introduction to GPS geodesy [15h]: Elements of Geodesy, GPS Technology, contributory error and accuracy, GPS Observables, measurements and strategies, Terrestrial Reference frame, Applications of GPS, GPS measurements and active crustal motions: Case studies, other space borne Geodetic techniques

Reference

1. Potential Theory in Gravity and Magnetic Applications – R.J.Blakely
2. Gravity and Magnetic Methods by Rao B.S.R and Murthy I.V.R
3. Applied Geophysics by W.W. Telford
4. Fundamentals of Geophysics by William Lowrie
5. Gravity and Magnetic Exploration- Principles, Practices, and Applications. – W.J.Hinze, Ralph R.B. von Frese, A.H.Saad

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SEMESTER II

RT-001: PLASMA PHYSICS

Introduction [5h]: Definition of plasmas, Debye shielding, Theoretical approaches to study plasma, difference between laboratory and space plasma, application of plasma

Single particle motion [10h]: Particle motion in constant electric field, magnetic field, time varying magnetic field/electric field, Particle drifts in earth's magnetic field, Concept of adiabatic invariants and their conservation.

Waves in Plasmas [7h]: Approaches to study plasma (fluid/kinetic), introduction to fluid theory, application of fluid theory to understand-Plasma oscillations, waves in unmagnetized plasmas, waves in magnetized plasmas, Plasma waves and Introduction to simulations.

Fluid and kinetic theory of plasma [8h]: Linear and Nonlinear fluid theory of plasma waves, kinetic theory of plasma waves, hands-on sessions with Mathematica/MatLab

References

1. Introduction to plasma physics, F. Chen
2. Fundamentals of Plasma Physics by JA Bittencourt
3. Introduction to Plasma Physics: With Space and Laboratory Applications by D. A. Gurnett, A. Bhattacharjee.
4. Waves in Plasmas, by Thomas H. Stix

RT-002: IONOSPHERIC PHYSICS

Basic Concepts and radio wave propagation *[10h]:* Earth's Atmosphere, collision processes, chemical kinetics, ionization by EUV and particle radiation, heating and cooling processes, neutral upper atmospheres, exosphere and ionosphere, Ionospheric regions/layers (D-, E- and F-regions), Basic ionospheric processes, dynamo action in Ionosphere, E- region Dynamo Theory, F- region dynamo theory, electrical conductivity of ionosphere. Radio wave propagation, derivation of Appleton-Hartree equation.

Large Scale processes in the Equatorial Ionosphere [10h]: Equatorial Electrojet (EEJ), Counter Equatorial Electrojet (CEEJ), Sporadic E, Blanketing Es, Equatorial Spread F (ESF)

Basic ionospheric measurement techniques *[10h]:* Ionosonde, radar (incoherent, coherent, MF etc), satellite (GPS, GLONASS etc.), spaced receiver scintillation experiments, airglow experiment,

Radio occultation technique, VLF measurements, Riometer, ionospheric and neutral atmospheric models global models

References

1. Introduction to ionospheric physics; Academic Press, Inc., 1969 by Rishbeth, H., and Garriott
2. The solar-terrestrial environment by Hargreaves, J. K.
3. Kelley, M. C., The earth's ionosphere; plasma physics and electrodynamics; Academic Press, Inc., 1989.
4. Ionospheric Radio by Kenneth Davis

RT-003: Magnetospheric physics

The Sun [4h]**:** Interior of the Sun, Solar atmosphere, sun as a magnetic star, solar wind, interplanetary medium, quiet and active sun, Flares and coronal mass ejections (CMEs), collisionless shocks, solar activity, periodicities in solar activity, sunspot

Introduction to Earth's magnetospheres [13h]:

Part-1 : Earth's magnetosphere: Formation, structure, different regions- bow shock, magnetosheath, magnetopause, plasmasphere, radiation belts, ring current, cusp regions, auroral zone, current sheet, southern/northern lobes waves in magnetosphere. Formation and dynamics of planetary magnetospheres.

Part:2 Plasmas and currents in the magnetosphere, The open magnetosphere and reconnection, disturbances, geomagnetic storms and substorms, aurora, energetic particles in the magnetosphere, space weather, geomagnetic activity indices

Magnetohydrodynamic concept [8h]: Introduction, concept, basic assumption, ohms law, MHD equations, frozen in concept, application in solar wind and Earth's magnetosphere.

Planetary Magnetosphere [5hrs]

References

1. Basic Space Plasma Physics by Wolfgang Baumjohann
2. Introduction to plasma physics, F. Chen
3. Quantitative aspects of magnetospheric physics by Lyons, and Williams – 2013
4. Origins of Magnetospheric Physics by James A. Van Allen

RT-004: MATHEMATICAL PHYSICS

Ordinary Differential Equations [10h]: Basic Concepts, First Order Equations, Second order Equations, Higher Order Equations, Series solutions and Special Functions (Legendre functions, Bessel functions, others. Tutorials and hands on practice

Partial Differential Equations [10h]: Introduction, Elliptic Equations, Laplace operator, Hyperbolic Equations, Wave equation, Parabolic Equations, Diffusion Equation, Laplace transform, Fourier series, Green's Function, Perturbation, tutorials and hands on practice

Complex analysis [10h]: Introduction, Complex Integration, Cauchy's Integral, Residues, tutorials and hands on practice

References

1. S. D. Joglekar, Mathematical Physics: The Basics, Universities Press 2005
2. G. Arfken and H. J. Weber: Mathematical Methods for Physicists, Academic Press 2005
3. A.K. Ghatak, I.C. Goyal and S.J. Chua, Mathematical Physics, McMillan

RT-005: GEOPOTENTIAL METHODS

Basics [8hrs]**:** Basic concepts, Earth's magnetism and gravity, potential field equations and derivations, geomagnetic and gravity fields, density and susceptibility of rocks and their determination, Figure of Earth, Geoid and Isostacy.

Survey & Data Reduction[10hrs]**:** Instruments for magnetic and gravity surveying, magnetic and gravity surveys- ground, airborne, marine and satellite, Correction and reduction of gravity and magnetic data, crustal magnetic and gravity anomalies and their sources.

Data Processing & Interpretation Techniques [12hrs]**:** signal processing as applicable to gravity and magnetic data processing, magnetic and gravity data processing and interpretation, different techniques for estimating depth to basement, case studies.

References

1. Potential Theory in Gravity and Magnetic Applications – R.J.Blakely
2. Gravity and Magnetic Methods by Rao B.S.R and Murthy I.V.R
3. Gravity and Magnetic interpretation in Exploration Geophysics by I.V.R. Murthy
4. Applied Geophysics by W.W. Telford
5. An Introduction to Geophysical Exploration by Philip Kearey , Michael Brooks and Ian Hill
6. Fundamentals of Geophysics by Willium Lowrie

7. Gravity and Magnetic Exploration- Principles, Practices, and Applications. – W.J.Hinze, Ralph R.B. von Frese, A.H.Saad

RT-006: ELECTRICAL AND ELECTROMAGNETIC METHODS

***Electrical methods [12hrs]*:** Classification of electrical methods, Electrical properties of Rocks and Minerals, Factors effecting the resistivity, Elementary theory, Archie's law, Equivalence and Suppresion principles, Darzarrouk parameters, types of resistivity curves, electrode layouts (Werner, Schlumberger, Dipole-Dipole, two and three electrode configurations) and field procedure, processing and interpretation of resistivity data, case studies.

***Electromagnetic Methods [18hrs]*:** Electromagnetic induction principle, Maxwell's equations, Diffusion equation, Skin depth relation, Factors controlling the depth of penetration, Impedance equations for 1D, 2D and 3D Earth, Impedance response for a layered Earth, Classification electromagnetic methods: Active and Passive methods, Sources, Active methods: Principles, Turam, Slingram, VLF, Tilt angle methods, data acquisition, processing and interpretation techniques, Passive methods: Principle of magnetotelluric method, Field procedure, Instrumentation, MT data processing, Dimensionality and directionality analysis, Static shift, Induction arrows, 1D, 2D and 3D interpretation of MT data, Applications, Geomagnetic depth sounding, Field survey and instrumentation, Magnetograms, Induction arrows, Z/H pseudo sections, Thinsheet approximation, 2D and 3D Interpretation procedures, Case studies

References:

1. Applied Geophysics, W.M. Telford et.al.
2. Electrical Methods in geophysical prospecting by George V.Keller
3. D.C Geo electric sounding by P.K.Bhattacharya and H.P.Patra
4. Geo sounding Principles, Vol 1 by O.Koefoed
5. Electrical methods of Geophysical Prospecting, Keller and Frischknecht
6. Magnetotelluric method, Keller and Kaufman
7. Simpson, F. and Bahr, K., 2005. Practical magnetotellurics. Cambridge University Press.
8. Chave, A.D. and Jones, A.G. eds., 2012. *The magnetotelluric method: Theory and practice*. Cambridge University Press.

RT-007: INTRODUCTION TO WEATHER AND ATMOSPHERIC PROCESSES

Basics [6h]: Structure and composition of the atmosphere, Weather elements and definitions Moisture variables, Virtual/potential temperature

Atmospheric Stability [6h]: Lapse rates, Stability in the atmosphere, heat balance of the earth-atmosphere system. Mixing heights, Divergence and Convergence, Advection and Convection, Barotropic and baroclinic stability, quasi geostrophic approximation, Hydrodynamic instability

***Fundamental Forces** [6h]:* Equations of motion on a rotating earth, Balanced flow, Winds, wind roses and wind profiles, Thermal wind and Vertical motion, Rossby, Richardson, Reynolds and Froude Numbers. Turbulent diffusion equation – Eddy transport of heat, mass and momentum, Bjerknes' Circulation theorem and applications, General circulation

Weather systems [6h]: Condensation and precipitation, clouds and their classification, cumulus convection, convective storms, fronts and frontogenesis, monsoons, jet streams, extratropical and tropical cyclones.

Climate [6h]: General circulation, climate system, climate variability, numerical weather prediction and climate models, climate science and climate change

References

1. An Introduction to Dynamics Meteorology by J. R. Holton
2. Physics of Climate by Peixoto and Oort
3. Contemporary Climatology by P. J. Robinson and A. H. Sellers
4. Numerical Prediction and Dynamic Meteorology by G. J. Haltiner and R. T. Williams

RT-008: CLIMATE DYNAMICS AND MODELLING

Evolution of climate: different concepts [6h]: Evolution of Earth's atmosphere (composition of primitive atmosphere, energy balance), Earth's early climate, Paleo climate and paleo-climatic record. Ice Sheets and Climate

Global circulation pattern [6h]: Basics of global circulation (Hadley, Ferrel, Polar cell and Walker circulation), Basics of Oceanic circulation (Thermohaline circulation, different ocean currents and heat transport). Concept of monsoon system (Large Scale Dynamics and features), Indian monsoon, East Asian monsoon, African monsoon, Australian monsoon and South American monsoon

Global Teleconnections [6h]: ENSO basics, IOD basics, Climate Change & El Nino, The Atlantic Multidecadal Oscillation, The Pacific Decadal Oscillation, Quasi-biennial Oscillation

Climate Change and Climate Modeling [6h]: Concept of climate change, natural climate change, Anthropogenic Climate Change, Climate Sensitivity and Feedback Mechanisms, Basics of General Circulation Models (Numerical Modeling techniques), their evolution and Coupled Atmosphere-Ocean Processes. Introduction to the IPCC Climate Model Simulations

***Introduction to Mountain climate [6h*]:** Concept of mountain meteorology, interactions with large scale circulation. Mountain snow and regional climate

References

1. Frederick K. Lutgens, Edward J. Tarbuck, Dennis G. Tasa: Atmosphere, An Introduction to Meteorology (13th Edition)
2. Hartmann, D. L.: Global physical climatology (Vol. 103). Newnes
3. Tom S. Garrison: Oceanography: An Invitation to Marine Science
4. Barry, R. G.: Mountain weather and climate. Psychology Press

RT-009: PALEOMAGNETISM, ARCHEOMAGNETISM AND ENVIRONMENTAL MAGNETISM

Palaeomagnetism [10h]: Pleomagnetism-Basic features of the Earth's Magnetic Field, GAD Hypothesis, Rockmagnetism- Induced and Remanent Magnetism, Magnetic susceptibility, types of magnetic remanence, magnetic properties, common magnetic rocks and minerals, sampling, measurement and instrumentation. Different techniques in the analysis of rock samples-transformation of coordinate system, Demagnetisation, Display of remanent magnetic directions, analysis of vector components; Display and statistics of Paleomagnetic data; paleomagnetic poles and APWP, Global magnetic polarity timescale, Magnetic polarity stratigraphy, Relative Paleointensity determination from sediments-Psuedo-thellier approach, Anisotropy of magnetic Susceptibility.

Archaeomagnetism [8h]: Archaeological artefacts, Historical monuments, Earth's magnetic field, Rock-magnetic properties, Firing temperature, Natural remanent magnetization, Thermoremanent magnetization, Partial thermoremanent magnetization, Thellier and Thellier method, Absolute geomagnetic field, Cooling rate correction, Anisotropy of thermoremanent magnetization, Archaeointensity, Palaeo-secular variation curve, Archaeomagnetic dating.

Environmental Magnetism [12h]: A multi-disciplinary approach; Environmental magnetism and Paleomagnetism, Magnetic properties of Solids, Fundamentals of Environmental magnetism, natural Magnetic minerals, magnetic properties of Natural Materials, Techniques and methods of magnetic susceptibility and remanence measurements; Depositional signals in continental and marine records, environmental magnetism and its application to Indian depositional settings, Magnetic susceptibility and depositional environments, magnetic mineralogical s-ratio and paleoclimate in in sediments, application of environmental magnetic methods for paleoclimate, pollution etc.

References

1. Dunlop, D. J., and Ö. Özdemir (1997), Rock Magnetism, Fundamentals and Frontiers, Cambridge Univ. Press, Cambridge,U. K., doi:10.1017/CBO9780511612794
2. Hus, J., R. Geeraerts and S. Spassov. 2003. Archaeomagnetism and archaeomagnetic dating.
3. Mchelhinny, M.W, and McFadden, P.L.(2000). Paleomagnetism: Continents and Oceans, Academic Press, UK
4. Thompson, R., and F. Oldfield (1986), Environmental Magnetism, Allen and Unwin, Winchester, Mass., doi:10.1007/978-94-011-8036-8

RT-010: EARTHQUAKE AND IONOSPHERIC SEISMOLOGY

Earthquake dynamics [12h]: Plate Tectonics, plate motion, types of Faults, Earthquake kinematics and dynamics, Seismic Cycle Model, Determination of Earth structure, Types of Tomography Analysis, Seismotectonics. Theory of elasticity, generalized Hooke's law, different types of elastic waves and their propagation characteristics, equations of motion of seismic body waves, Attenuation and dispersion of seismic waves, Analysis of seismograms and identification of various phases on the seismograms. History of seismometer, Basic Theory of Seismometer, Seismic Network, Epicenter Location, Theory and algorithm of Hypocenter Determination, Terms and parameters of seismic faults, Focal mechanism diagram, determination of focal mechanism by P-wave first motion method, Basic structures of the earth, Analysis of Tele seismic Waves, Information contained in Seismogram, Receiver Function Analysis.

Lithosphere-Atmosphere-Ionosphere Coupling and Ionospheric Seismology (Interdisciplinary) ***[10h]:*** Various forcing affecting atmosphere-ionosphere system from above and below, lithospheric forcing, natural seismic events, lithosphere-atmosphere-ionosphere (LAI) coupling - synergy between different ground surface, atmosphere and ionosphere processes - (i) chemical (ii) electrodynamical (iii) electromagnetic and (iii) mechanical channels, various experimental techniques to observe LAI coupling, earthquake precursory signals, ionospheric seismology

Paleoseismology [8] : Introduction to Paleoseismology, The Scope of Paleoseismology, Identifying Prehistoric Earthquakes from Primary and Secondary Evidence. Prehistoric Earthquake Recurrence and Dating. Estimating the Magnitude of Prehistoric Earthquakes, The Early Development of Paleoseismology, Field Techniques in Paleoseismology, Paleoseismology of different tectonic environments, Using Liquefaction-Induced Features for Paleoseismic Analysis, Overview of the Formation of Liquefaction-Induced Features, Criteria for an Earthquake-Induced Liquefaction Origin, Historic and Prehistoric Liquefaction--Selected Studies, Features Generally of Nonseismic or Unknown Origin, Estimation of Strength of Paleoearthquakes.

Reference:

1. The Solid Earth: An Introduction to Global Geophysics by *C.M.R. Fowler*, Cambridge University Press
2. Fundamentals of Geophysics by *W. Lowrie*, Cambridge University Press, London.
3. Applied Geophysics by *W.M. Telford, L.P. Geldart, R.E. Sheriff and D.A. Key*, Cambridge University Press, London.
4. Pre-Earthquake Processes: A Multidisciplinary Approach to Earthquake Prediction Studies, AGU Monograph, 2018. Editors: Dimitar Ouzounov, Sergey Pulinets, Katsumi Hattori, Patrick Taylor
5. Earthquake prediction: An overview, International Handbook of Earthquake and Engineering Seismology. Kanamori, H. (2003),Int. Assoc. Seismol. Phys. Earth's Int., 81B, 1205–1216.

6. Paleoseismology by James McCalpin
7. Active Tectonics and Alluvial Rivers by EAN F AUTOR DUMONT, Stanley A. Schumm, Schumm A, Jean F. Dumont, John M. Holbrook
8. Geotechnical eartqhuake Engineering by Milutin Srbulov
9. The Geology of earthquakes by C.Allen, K.E.Sieh and R.S. Yeats

Additional Reading:

10. The dynamic Earth by *P.J. Wyllie*, John Wiley & Sons, NY.
11. Physics and Geology by *J.J. Jacobs, R.D. Russel and J.T. Klilson*, McGraw-Hill International Series in the Earth and Planetary Sciences.
12. Fundamental of Geodynamics by *A.E. Schieddeggar*, Springer
13. Introduction to Seismology by *Peter M. Shearer*, Cambridge University Press, London.
14. An Introduction to Seismology, Earthquakes and Earth Structure by *S. Stein, and M. Wysession*, Wiley-Blackwell, Oxford.

RT-011: GEOLOGIC AND TECTONIC FRAMEWORK OF INDIAN SUB-CONTINENT

Cratons [10h]: Physiographic provinces of India, Cratons of the Indian shield- Dharwad, Bastar, Singhbhum, Chhotanagpur Granite-Gneiss Complex, Rajstan Craton, Meghalaya Craton

Fold Belts *[8h]*: Aravalli Mountain Belt, Himalayan Fold Belt, Central Indian Fold belts, Singhbhum Fold Belt, Eastern Ghat Mobile Belt, Pandyan Mobile Belt.

Sedimentary Basins *[6h]*: Proterozoic, Mesozoic and Cenozoic

Tectonics and Evolution of Arabian Sea & Bay of Bengal *[6h]*

References

1. Geology of India – D.N.Wadia
2. The Making of India: Geodynamic Evolution – K. S. Valdiya
3. Geology of India: Volume 1 and Volume 2 – M. Ramakrishnan and R. Vaidyanathan
4. Deep continental structure of India: A preview, T.M. Mahadevan, 2003, Geological Society of India.
5. Cratons & Fold Belts of India – R.S.Sharma
6. Geology of States, Text Book Series- Geological Society of India
7. The Indian Ocean: a perspective. R.S.Gupta & E.Desa
8. Petroliferous Basins of India, Petroleum Asia Journal. Bhandari, L.L., Venkatachala, B.S., Kumar, R., Swamy, S.N., Garga, P. and Srivastava, D.C

Examination Pattern

Paper name	Written test Marks[#]	Internal assessment Marks[*]	Total Marks
Semester -I			
Core course I	60	40	100
Core course II	60	40	100
Core course III	60	40	100
Elective	60	40	100
Elective	60	40	100
Semester -II			
Elective	60	40	100
Elective	60	40	100
Elective	60	40	100

#For 60 marks written exam comprising of objective and subjective questions & it will be conducted by APC at the end of 1st semester.

*40 marks are for internal assessment by the faculties those are teaching the respective courses. Faculties can submit their assessment report to respective course coordinator at the end of first semester. This assessment shall be based on assignments/class-room test/ problem solving/seminar etc. conducted during the semester period. This internal assessment is to track the student's progress during the semester.